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NOTES ON DETAILS OF CONSTRUCTION AND ARRANGEMENT OF MARINE MACHINERY.

BY LIEUTENANT EMIL THEISS, U. S. NAVY.

In the following I desire to draw attention to certain details of construction, chiefly of a minor nature, in connection with the machinery and appurtenances coming under the supervision of the engineer officers of our ships, that are often slighted, or in regard to which the machinery specifications are either silent or not sufficiently concise, and which are therefore frequently evaded.

What I shall have to say is the result of observation and experience on two of our latest battleships, the *Alabama* and the *Kearsarge;* and while doubtless much or all is familiar to the readers of the JOURNAL, it may still serve a useful purpose to present this information in the shape of an article, to elicit discussion, to draw the attention of inspectors to the several points, and to lead, perhaps, to such changes and additions in the specifications as will prevent the repetition of omissions and defects with which all sea-going engineer officers have to contend.

Generally speaking, the design and construction of the machinery of our naval vessels is excellent, and, as stated above, my remarks will deal largely with minutiæ; still every one knows that the little things enter largely into the success or failure of a particular machine, inasmuch as they make it easy or difficult to keep it in proper working order. The accessories may be such that it is easy to serve or overhaul the machine adequately and readily, or they may be insufficient and themselves demand time and attention which should be bestowed on more important work.

A word about the main-engine framing: It is my opinion that a system of framing, properly stayed, consisting of an inverted Y frame at the back, with two inclined forged-steel columns in front, is to be preferred to the elaborately braced frames consisting entirely of round forged-steel columns. It is simpler, stiffer, and leaves the engine parts more accessible for overhauling. Speaking about overhauling, more attention should be paid to facilities to be provided for such work. Almost without exception, brasses and caps have to be drilled and tapped for eyebolts; special contrivances have to be fitted up for hooking tackles, for supporting crosshead slippers, etc., all of which should have been provided by the builders. The means provided for lifting the cylinder heads and bonnets were inadequate on both of the ships on which these remarks have a special bearing. With the scanty head room permitted, it is always difficult to find means for quickly lifting the heads of the I.P. and L.P. cylinders, but it can be done. In every case the inspector should insist that the contractors furnish a demonstration of the practicableness of the gear provided by removing the heads and bonnets in his presence or that of one of his assistants, because frequently the gear, while mechanically correct, is rendered useless by obstructing pipes and fixtures run in after the design has been approved.

Much trouble has been experienced with piston rings, especially with those of the H.P. cylinders. It seems to be impossible to prevent the entrance of steam back of the rings, setting the latter out unduly, thereby causing excessive and irregular wear both of the cylinder and the rings. Besides, where, as is the

usual practice, two rings are fitted, there exists a tendency to wear shoulders into the cylinder, both at top and bottom, opposite the joint between the rings. The difficulty has been entirely overcome by fitting a single ring, which, while yielding to outside pressure, and therefore sufficiently elastic, is prevented from being set out beyond a fixed diameter by means of a strap securely bolted to the inside of the ring, a fitting piece being provided, so that by filing it down or shimming out, the point beyond which the ring will not stretch, can be accurately controlled. In designing a ring of this nature it must be borne in mind that all fittings must be of a most substantial character, strongly secured, as the straining and jarring to which the parts are subjected are very trying. The piston rings for the I.P. and L.P. cylinders are best made in sections, with tongue pieces well secured. Such rings have worn well on the *Alabama*, while the single rings, as fitted on the *Kearsarge*, are unreliable. The sectional rings have the further advantage that they can be examined and removed without having to lift the cylinder heads.

Another main engine fitting to which I wish to direct attention is the piston-rod packing. The essentials of a good piston-rod packing are:

(1) Elasticity; it must be able to adjust itself to slight inequalities in the diameter of the rod or divergence from a true circular cross section; and it must accommodate itself to the rod should the latter not be centered exactly or the engine be somewhat out of line.

(2) Steam tightness; it must guard against leakage of steam not only along the rod but also between and back of the packing.

(3) Small number of parts; it should have as few parts as possible, and especially should screws or similar fastenings be avoided; and where their use is unavoidable, the parts should be so joined that no strain will come on the screws.

(4) Easy pressure on rods; the pressure of the packing on the rod should be only great enough to prevent leakage, and never so great as to grip the rod and cause sudden heating. Where the packing consists of rings of triangular cross section, the sections of packing rings being left open at the butts, the

angle at which the successive rings are fitted together should never be less than forty-five degrees.

(5) Ease of removal; all the above requirements being fulfilled, it is desirable that the packing be so constructed as to make it possible to renew any part without the necessity of taking the piston off the rod.

It is very evident that the ordinary form of a well-known make of metallic packing, which is very extensively used in our naval vessels, does not answer all the above requirements. It is entirely too unyielding, and, unless the engine is very rigid and in perfect alignment, there is danger of shouldering the rods. An "improved" form of this packing was tried in the H.P. stuffing boxes of the *Alabama*, but this design did not meet the requirements of paragraphs (2), (3) and (4), in that it permitted leakage of steam back of the packing, that it consisted of parts fastened together by screws which frequently came adrift, and that the angle of the packing ring sections was so acute as to lead to gripping and heating of the rods. At present an experimental packing furnished by the same company, and made to satisfy the requirements above laid down, is being tried and has given satisfaction so far.

A most important detail, which is sometimes slighted, is the oil service. The machinery specifications have for some time called for oil boxes with both valve drips and wick feed tubes. The latter are indispensable for ordinary cruising speeds, if proper economy in the use of oil is to be observed, especially if lard oil is supplied, as is the case on the North Atlantic Station. On the two ships in question, only valve-regulated drip feeds were fitted originally, and wick-feed boxes were fitted later, in conjunction with the valve manifolds, with the result that the oil expenditure was cut down nearly fifty per cent. Wick-feed oil boxes may also be advantageously fitted for some of the auxiliaries now oiled by valve feeds alone, notably the ship's ventilating blower engines.

In the lead of oil pipes great care should be taken to make it as direct as possible, and particularly to avoid return bends in an athwartship vertical plane. It may seem superfluous to empha-

size this, but it is an essential sometimes lost sight of. With pipes run without regard to this requirement, a roll of the ship will spill out the accumulated oil, and the feed stops until enough oil has accumulated for another gush. Too much attention can not be paid to the matter of securing an efficient oil service, and the arrangement of the oiling system should be worked out when working out the general engine design. The engine parts may be ever so well proportioned, if the oiling arrangements are defective, it will be difficult, impossible even, to prevent excessive wear. In addition to the oiling devices for crank pins and crosshead pins usually fitted, I should strongly recommend that centrifugal crank-pin oilers be always supplied, as well as a combined oil and water service through hollow indicator connections for the crosshead pins. The use of water in small quantities on these pins guards against heating and saves oil, the water making a species of lather with the oil, so that the latter goes farther. Another desirable addition to the oil service will be found in oil boxes under the crosshead guides, with dragglers secured to the slippers dipping into them.

Inasmuch as practically no internal lubrication is used in vertical marine engines, and none whatsoever in vertical auxiliary machinery, it seems superfluous to fit globe oil cups on valve chests and steam sight-feed lubricators on auxiliaries. The main engine steam sight-feed lubricator should remain, as also those for horizontal auxiliaries, such as ice machines; all others are always taken down before a new ship has been in commission two or three months. The steam sight-feed lubricators on dynamo engines are, or should, never be used, as experience has shown that these engines will run without them, and the safest plan, therefore, is not to fit them.

A few other points, and I shall be ready to pass to the next chapter. The lower brasses of the crank-shaft bearings should preferably have a flange at the crank-pit end, not extending the full length of the bottom of the brass, but only just long enough to hold the brass endways; this will permit of the introduction of liners under the brass should such be found desirable. The caps for crosshead-pin brasses should be so designed that it will be

possible to drop the slipper without having to remove the cap first.

The bolts securing the slippers to the piston-rod ends should never be so long that in order to back them out it is necessary to remove the stuffing-box packing, so as to give room to spring the rod. The heads of bolts securing the backing guides of main engines should have hexagonal extensions beyond the countersunk fillister heads, long enough to provide a good wrench hold. The dowel pins for holding the liners and parting pieces between brasses should always be long enough to protrude well through all the liners and extend into holes drilled into the other brass; this will prevent slipping and disarrangement of liners when handling the brasses.

Not much can nor need be said about the boilers. More attention should be directed to the methods used in fitting and riveting the furnaces into the tube sheets. The furnace flues are probably nearly cylindrical when they leave the manufacturers, at any rate the greatest difference of diameters at any section should not and need not exceed $\frac{1}{4}$ inch. After they are worked up into the boilers, however, unless great care has been taken to guard against deformation, differences of diameter as great as 1 inch are formed; and at the back end, where the furnace is initially weak anyhow, because of the uncorrugated length, the divergence from the circular form is often very pronounced. It is needless to say that such deformation must be accompanied by loss of strength. Greater care should be taken to secure tight work where circumferential and longitudinal joints meet in the shells of double-end boilers. Unless tight work is secured in the boiler shop, by the proper chamfering of longitudinal butt straps, all subsequent calking will not completely remedy the defect; the leaks will be stopped for a while and then break out again. The hand-driven rivets in the joints between heads and shell are often slighted likewise, and need subsequent calking. I am of the opinion that the clothing and lagging had better be left off the bottom of boiler shells. In both the ships referred to above, this lagging has been permanently removed, in order to give access to rivets and calking edges which occasionally

demand attention. Difficulty is always had in keeping joints in combustion chambers tight, where the furnace flange, the back tube sheet, and the side sheets of combustion chambers lap, and in every case it has been found necessary to fit several plugs into these laps riveted over at both sides into countersinks. I consider that it would be a good plan to fit inclined brick-lined shield plates opposite each furnace against the back sheets of combustion chambers; it has been done in all the boilers of both the *Alabama* and the *Kearsarge*. On the *Kearsarge* it was done after the official trial; on the *Alabama* it was done after the ship had been placed in commission. Little heating surface is sacrificed thereby, and the bulging of combustion-chamber plates, which is of such frequent occurrence, is effectually guarded against. More care should also be taken in building up of bridge walls, so that the escape gases will not impinge against projecting faces of partition walls, and, generally, the calorimeter over bridge walls should be increased. The plates over the holes near the bottom of the bridge-wall castings, which give access for cleaning in the combustion chambers under the bridge walls, should be secured with clamps or similar devices, not with tap bolts, as the latter usually twist off and have to be drilled out. The circulating plates in boilers should be suspended from the tubes, each by at least two clips, not stayed to one another across the water spaces. The flanges and fastenings of internal feed pipes should be of the ordinary light-service proportions, but should not be lighter than required for pipes designed for 50 pounds pressure, otherwise they will spring and a part of the feed water be sprayed into the steam space. Greater care is needed in fitting up the water columns, in order that the gauge-glass fittings may be brought more accurately into line. Many glasses are broken because of this lack of alignment.

I can see no particular advantage in the use of any but the ordinary gratebars; they are cheap, easily replaced, last longer than the complicated and heavy shaker bars, and are, on the whole, just as efficient. After a shaker bar, say of the St. John pattern, has been in use for some time, it becomes an expensive luxury to use the shaker arms, as the bars soon crack off near

the front end, and the slice bar has to be resorted to as with ordinary bars. Improvement is also possible in the fitting up of furnace fronts. The perforated wrought-iron plates on the fire side of furnace-front castings burn through very quickly, and then the casting begins to go, unless the liners are constantly renewed, which is expensive. Perforated, molded, hard firebrick would be preferable, in my opinion. The baskets for supporting the zinc protecting plates in boilers should be so made that all that it is necessary to do in order to prepare the zinc is to drill the hole for the clamping bolt; there should be no necessity for cutting or notching the plate in any way.

The floor-plate supports in fire rooms are, as a rule, made too weak for the heavy work carried on upon them, and have to be strengthened, sometimes only locally, under ash chutes and for anvil supports, sometimes all over. Heavy floor plates, one-half inch thick, with chamfered edges, should always be fitted under ash chutes. Provision should always be made, by means of shields and casings along boiler fronts, to keep ashes from falling into bilges, and effective means for accomplishing this end can and must always be provided.

The system of drains of main, auxiliary and dynamo steam systems should be kept entirely separate and distinct up to and including the traps. Some weight and complication are saved, when, as is the case on the *Alabama*, all these pipe systems are drained by the same set of traps, but the drawbacks are apparent without further explanation.

Trouble is experienced with safety-valve drains and drains from escape pipes getting choked with the cinders that fall down the escape pipes. This trouble has been overcome by fitting covering plates over the tops of escape pipes, with guides extending down inside the pipes, the plates kept from being blown away by slack chains.

The necessity for placing the fire-room blowers where they can be properly looked after has been emphatically demonstrated many times. The blower engines should be fitted with an efficient water service supplied from the fire main, not from pipes above the armor deck.

A word about the lagging of pipes. Almost without exception such pipes as drain pipes of steam-pipe systems, trap discharge pipes, return pipes of heater systems, are insufficiently covered with non-conducting material, with the result that the canvas covering is soon charred, and drops off. Also in certain locations, as over the boilers and close to them, and in other exceptionally hot places, canvas will not answer the purpose, and light galvanized iron should be used to case in the non-conducting material; galvanized iron should also replace canvas wherever the chances are that the covering will be subject to rough usage, as at boiler fronts, where shield plates, manhole plates, &c., play havoc with pipe covering. Greater efforts should also be made to fit lagging and clothing in such a way that important flanges can be made accessible quickly and without tearing or cutting the lagging; also, that the clothing or angle irons or flanges supporting the clothing or lagging do not come so close to flanges that bolts cannot be readily backed out. The wood lagging on condensers is almost always brought so near the end flanges of the condensers that it must be sawed off all around before a water chest can be unbolted. The lagging should stop short of the flanges, and the open space so left covered by a brass band. The trouble is that the work of lagging is done by men who do not know where overhauling will have to be done, and consequently, fail to make provision for it unless their work is well scrutinized.

The question of the proper joint material for high steam-pressure pipe flanges is one that is always an open one. No one will deny that a properly made and fitted gasket of corrugated copper is to be preferred to all others, provided the pipe flanges and the bolts are heavy and strong enough, and provided the faces of the flanges are accurately parallel. If the latter is not the case, copper gaskets cannot be used. Unfortunately the faces of pipe flanges are not always parallel, and it becomes a question what to substitute for corrugated copper. There are many excellent materials in the market, of about equal value, but I believe that the most reliable is a gasket made on the principle of the McKim gasket, manufactured by the McCord Co. I have used these

gaskets in trying places, as substitutes for corrugated copper, and have had others made on board, similar in principle, and they have given good results.

While on the subject of pipes, there are a few other points to which I wish to direct attention. Wherever possible important steam connections should be duplicated, at any rate over as much of the lead as is practicable, beginning at the source of supply. An example of such a connection is the galley steam pipe, which is in daily use. It is a good plan to have pipes so arranged that the dynamos can take steam either from the dynamo line or from the auxiliary steam system. On both the *Kearsarge* and the *Alabama* both connections exist, but in each case it was found expedient to arrange for another "emergency" connection, led in such a way and with valves so placed, that repairs can be effected on any part of the dynamo steam line and still at least two machines can be kept in operation, sufficient for lighting and ventilation. Some of the engine-room auxiliaries, notably the main air pump and the reversing engine, are often piped (and this is in accordance with the specifications) to exhaust, the former into the main condenser and the receivers, the latter into the main condenser only. They should exhaust into the auxiliary exhaust likewise, so that they may be moved by steam without sending the exhaust into the main condensers from which vapor will rise into the L.P. cylinders and valve chests and rust the surfaces. All steam pipe drains, and drains from evaporator coils, as well as the heater drains, should be led so as to discharge into the feed tank and into the main and auxiliary condensers at will. This is always specified for heater drains, and these have besides a discharge to bilge; this latter discharge is not needed for the other drains, though sometimes convenient, but the other leads should be as aforesaid. Such leads give complete control over the temperature of the water in the feed tanks, so that loss by evaporation in the tanks can be avoided and the filtering material maintained in a state of efficiency. Main engine jacket traps should discharge both to feed tanks and to main condensers. Boiling out connections should be fitted to the auxiliary condensers, as well as to the main, and

a steam connection should be fitted for blowing through the oil manifolds and pipes of main engines. The drains from cylinders and valve chests of auxiliary machinery should in every case lead to the engine exhaust, possibly with a branch to bilge.

Little need be said of the main condensers. They are well designed and the only trouble that has arisen has been due to improper material, cast material instead of a strong rolled bronze, for water-chest stays and bolts. The use of cast tube ferules also must be deprecated; they should be made of drawn material, and of the standard Bureau pattern. Zinc slabs have been secured to bonnets of main condenser heads, to auxiliary condenser heads, and have also been fitted in distillers and salt water ends of pumps with good results; the use of zincs in this machinery is now required by specifications.

The pumps on both the *Kearsarge* and the *Alabama*, including the main air pumps, are of the Worthington pattern and work well. As a rule more clearance should be given in the neck bushings of pump-rod stuffing boxes, particularly of the air pumps, and the stuffing-box glands should be beveled instead of flat. The specifications are now much more exacting than formerly as regards material for auxiliaries usually supplied by sub-contractors. A large number of iron studs have had to be removed and bronze ones substituted about salt water ends of pumps and also for suction and discharge valves in pump manifolds. All pumps located above the floor plates should be fitted with ample drip pans, with drains to bilge. Strange as it may seem, they are often conspicuous by their absence.

The feed tanks as arranged on the *Kearsarge* and *Alabama*, leave nothing to be desired. The specifications provide that all drains leading into them shall terminate well below the ordinary water level. For some reason this eminently rational requirement is frequently not complied with. What material is best for the filter bed is probably a question for discussion. I have used clean porous coke for some time, and find it to answer the purpose. Room for stowing can be usually found in some bunker too small and inaccessible or too hot for coal.

As regards arrangement of feed heaters, I prefer that on the

Kearsarge to that on the *Alabama*. In the former the exhaust steam, which is ordinarily the heating agent in either case, may be either passed through the heater on its way to the main or auxiliary condenser, *i. e.*, the exhaust steam coming from forward of the engine rooms, the pressure being regulated by a spring-loaded valve, or the by-pass valve may be opened, the spring-loaded valve unseated, and the steam allowed to back into the heater, the pressure in it being that due to the pressure in the auxiliary exhaust pipe or the receiver, as the case may be. In port the heaters are operated by passing the steam through, in at the top and out at the bottom, the water of condensation being carried along by the steam, and so assist the auxiliary condensers.

At sea, especially when the auxiliary exhaust is turned into the second receivers, the steam is allowed to back into the heaters. On the *Alabama* the arrangement is such that the steam can only back into the heaters, and they cannot, therefore, be effectively used in port. On the *Kearsarge* the feed heaters are not trapped, but the water of condensation may be drawn off through a 1-inch pipe leading to the main air-pump suction, a regulating valve serving to keep the water at nearly constant height in a gage glass, so insuring that the suction is water sealed. On the *Alabama* the heaters are trapped, the traps discharging to the main condenser. It is found, however, that the heaters have little effect unless the trap by-pass is kept open and a steady flow to the condenser is established. The feed heaters are, of necessity, heavy and cumbersome and very inaccessible for repairs; particularly this is the case on the *Alabama*. It is practically impossible to renew a tube, and to plug a leaky one is an undertaking demanding days. The greatest care should be exercised in the selection of tubes, so that none that is brittle is incorporated. If this is done a ship should be able to pass through a cruise or two without the necessity arising of plugging or renewing a single tube.

The shaft bilge and sanitary pumps are very useful, but care must be taken to make them of adequate size. On the *Kearsarge* they were of sufficient capacity for the work, and the sanitary pumps were piped so that the water could be passed through

the distillers in engine rooms or direct to the sanitary system. This should always be done. The bilge pumps should be large enough to keep the bilges clear with the ship steaming at ordinary cruising speed, say nine to ten knots. On the *Alabama* these pumps were too small to be of any use; besides, they were not fitted with air vessels, which are indispensable, and the sanitary pumps were not piped to discharge through the distillers. A satisfactory arrangement was secured by converting all shaft pumps into bilge pumps; by shifting the eccentrics opposite one another the same size of piping was made to answer the purpose. Air vessels were also fitted, and the pumps are now just about able, at cruising speeds, to keep the engine-room bilges clear. These pumps are single-acting, six inches diameter of plunger by four inches stroke.

Bilge pumps naturally suggest bilge drainage, and here I should like to say a word in favor of the general adoption of a system of bilge drainage for engine and fire rooms, and dynamo rooms as well, as it exists on the *Kearsarge*. The bilge suctions to all these compartments were so arranged that the shaft bilge pump and the engine-room fire and bilge pump could draw from any and all the compartments and from the crank pits on the same side of the ship without recourse to the secondary drain system, with its long and multitudinous connections, extending all over the ship, and its regiments of valves. The result was that all the bilges could be pumped dry quickly by the pumps designed for the purpose. The suction to each compartment—all were 3-inch pipes—was entirely separate and distinct up to the bilge-suction manifold, of which there was one in each engine room, and from these manifolds a single suction pipe led to the fire and bilge pump and to the shaft bilge pump. A few changes were made in the system after the ship had been commissioned to make it more complete and to make it possible to keep the engine-room bilges practically dry, at sea as well as in port. All bilge drains in the engine rooms were led into the crank pits, and as these were rather shallow and filled rapidly, it became imperative to have uninterrupted suction from them. A pipe with valves properly placed was therefore fitted by-pass-

ing the bilge-suction manifold in each engine room, so that the shaft pumps could be kept steadily on the crankpits, the steam pumps being used only whenever it became necessary to pump from the remoter compartments. The shaft pumps, both bilge and sanitary, being of adequate capacity, and the pipe system complete, it was unnecessary, at sea, to use steam pumps at all for bilge, sanitary and distilling purposes, except, at intervals, for pumping fire-room and dynamo-room bilges, resulting in a considerable saving of steam. Of course, to pump bilges on one side of the ship by pumps located on the other side, recourse had to be had to the athwartship connections of the secondary drain.

A supplementary system of bilge drainage pipes for the engine rooms was run in on the *Alabama* and is found very useful. It extends to all pockets and close places not otherwise reached, and also has suction branches to a small slop tank, to the filter chamber of the feed tank and the body of the feed tank, and also to the waste-water tank, which is located in the coal bunker just forward of the starboard engine room. This latter connection makes it possible to pump this tank when the special pump is being overhauled. The connections to the feed tanks are found very useful when these are to be cleaned.

Some points which I neglected to mention in connection with pipes and pipe covering may find space here; all pipes that are liable to sweat, such as pump suction and delivery pipes, fire mains, &c., in engine and fire rooms had better be clothed and lagged. The steam and drain pipes of the various heater circuits, leading as they do all over the ship, and hard to trace, should be tagged wherever it is difficult to identify them, so that the proper valves may be closed at once and defects made good without delay.

On both the *Kearsarge* and the *Alabama* the main feed pumps are located in the engine rooms, and I consider such location an excellent one. They can be kept clean and in good condition, and, being so close to the feed tanks, good suction is assured, even when the water is hot. The air valves on valve chambers should be piped to discharge back into the feed tanks, as other-

wise much water may go to waste. Improvement is desirable in the design and fitting of pump relief valves, particularly of the main and also of the auxiliary feed pumps. The springs should be long enough to make it possible to adjust the pressures at which the valves will lift with some degree of accuracy, and so placed as to be easily accessible for adjustment. The springs are often made so short and with coils so close that the merest touch of the nuts will make a difference of 100 pounds or more in the pressure at which the valves will lift, and the adjusting nuts are usually in the bilge.

There exists a difference of opinion as to whether the engine rooms are the proper place for the location of evaporators and distillers. I consider it a most excellent location, provided there is not too much crowding. The evaporators should under all circumstances be placed high enough so that the tubes may be drawn out over the floor plates and clear of the shell, and the distillers should be so placed that it is practicable to drop out the tube nests. A little more space should be allowed for bolting flanges of steam heads than exists, for example, in the case of the *Alabama's* lower evaporators. The work of loosening and setting up the nuts on these flanges was tedious and trying until clearances had been chipped for them, and even now a number have to be set up with hammer and chisel. The shells of evaporators, particularly the upper half, gussets, stays, &c., should be designed not so much to resist a certain moderate pressure as to supply as much material as weight considerations will permit and good sense will dictate, for the reason that internal corrosion proceeds very rapidly and is difficult to check. It would be advisable to fit an internal doubling plate along the highest part of the shell, above the dry pipe. Rivet heads also corrode away rapidly, but it is difficult to suggest an effective and practical remedy. No matter where an evaporator is placed, the pipes for circulating the cooling water through its distiller should be such that at least two pumps can be used for this service. The fresh-water pumps should always be so piped that each one may discharge independently either to the ship's tanks or to the feed tanks.

Wherever it is contemplated to install an ice-making and refrigerating plant of more than one ton capacity per diem, I believe rather in the duplication of the 1-ton machine, than in the fitting of a single 2-ton plant. The refrigerating plant as installed in the *Alabama* leaves little to be desired. One machine is capable of keeping the cold-storage rooms chilled, while the other is used for ice making. Whenever it becomes necessary to stop one for repairs, the other is available for the cold storage. It will always be found advisable to provide for an emergency connection to the circulating pipes from the fire main, and also for a discharge from some convenient pump in the engine or fire rooms to the circulating-pump suction. The cooling coils should always be tinned, inside and outside, and even then it is well to guard against pitting by sheets of zinc slipped under them. It may happen that, as the refrigerator piping is a continuous series all through the cold-storage compartments, the last compartment is not sufficiently chilled, while the first ones are unnecessarily cold. On the *Alabama* it so happened that this last compartment was the crew's space, which often contained several thousand pounds of meat. To make the temperatures more uniform throughout, a cold-air by-pass was fitted to the crew's compartment, and by slightly opening the by-pass valve the crew's compartment can now be chilled without robbing the remaining compartments to any serious extent.

It may appear that I have dwelt unduly on many points, intrinsically small and unimportant, and have very likely omitted others of greater weight. But I began by saying that I wished to unearth and present the many little things that are so often lost sight of, and which, added together, total up to an amount of work in the way of changes which is not at all inconsiderable, and which might just as well be done before the ship leaves the hands of the builders. Other defects to which I have alluded in the foregoing are due to oversights in design or construction, which have only to be mentioned to be corrected in future work, but which might be repeated unless attention was called to them. Let it not be understood that, in what I have said, I have in any way desired to make comparisons between the two ships which

furnished my text. Each has its shortcomings and each its excellencies, and each is abundantly able to stand on its merits.

Finally, I feel that I must apologize for the unsystematic manner in which I have presented my notes. My excuse is that the time of the senior Engineer officer of a large ship is so largely taken up by his duties, and his moments of leisure so often interrupted, that he cannot acquit himself of a task like the present one as he would wish.

RESULTS OF INVESTIGATIONS ON RECENT ENGINES OF THE GERMAN NAVY.*

[Translated for the JOURNAL by A. H. RAYNAL.]

Repeated cases of breakages of propeller blades and their fastening bolts on some of the later cruisers, as well as the breaking of the propeller shaft of the torpedo boat *S. 42*, were the cause of an investigation into the degree of uniformity of the stresses on the shafts in the new vessels of our Navy.

In Plates 1 to 16 are shown acceleration and tangential pressure diagrams of the respective engines for the maximum results obtained on their trial trips. In printing, the plates are reduced, so that the scales should be taken from the plates. In the large table are placed together the necessary data of construction and the results of the investigations.

The acceleration pressures on the tangential pressure diagrams are computed according to Radinger, taking into account half of the weight of the connecting rods, after it had been ascertained that such diagrams varied but slightly from those made in accordance with the more exact method of Lorenz.

On plate II are drawn diagrams for one engine according to both methods, in order to show their differences. The more exact method of Lorenz results in larger maximum and slightly smaller minimum values. But since it is rather the intention to get comparative data for the different engines than to obtain the absolute values of the tangential pressure, the handier method according to Radinger was deemed sufficient.

The results have been supplemented by some other data that were necessary to judge of the general efficiency of the engines. We start with the proposition that it is desirable—

(1.) To obtain as nearly as possible uniform tangential pressures, so that the disadvantageous stresses on the shaft, caused

* By Chief Naval Constructor Köhn von Jaski. "Schiffbau" of June 8, 1900.

by the varying amounts of the power transmitted, shall be reduced to a minimum, for long continued variations in the turning moments may ultimately lead to the breaking of the shaft;

(2.) To load the reciprocating parts for all the cylinders as uniformly as possible, that they may be made of equal dimensions, without making some of them unnecessarily heavy;

(3.) To divide equally among all the cylinders the total temperature range, that there may be a minimum difference of temperature in each cylinder.

In accordance with these propositions, we have ascertained for each cylinder of the engines under consideration the maximum and minimum tangential pressures, the maximum pressures on the rods, and the temperature ranges, and have tabulated them together for comparison.

The pressures on the rods have been taken from the indicator and acceleration diagrams in such a manner that the maxima of the absolute steam pressures, either added to or subtracted from the acceleration pressure on the respective pistons for each cylinder, have been entered in the columns 47–50, while in column 51 are given the ratios of the largest and smallest maximum pressures on the piston rods.

Under the head of temperature ranges, we have given those ranges of temperature that correspond to the steam pressures at the dead points as shown by the indicator for each cylinder, and in accordance with the well-known tables of saturated steam by Fliegner.

We must regard apart from the others the engines of torpedo boat *S. 42*, because they work at much higher revolutions and piston speeds. The higher acceleration pressures resulting therefrom cause a much more irregular stress on the shafts than the smaller amount of acceleration pressures in the slower-running engines of the larger vessels. But since several successive trial engines were built for this torpedo boat *S. 42*, the four-cylinder engine with cranks at right angles having been rebuilt in accordance with data from Mr. Schlick, the three different engines of this vessel offer interesting comparisons with one another. The

tangential pressures and the temperature ranges are nearly equally uniform in the three-cylinder and in the four-cylinder engines with cranks at right angles; in fact a little more favorable to the latter. To judge from the diagrams obtained, the tangential pressures of the four-cylinder engine would have been more uniform if the steam admission to the L.P. cylinder had been shorter, thus decreasing the work of the I.P. cylinder and correspondingly increasing the work in the L.P. cylinder.

The pressures on the rods would then also have been more uniform; as it was, the comparison with the three-cylinder engine was very unfavorable.

Comparisons of the two four-cylinder engines show plainly that it is not admissible, simply for the purpose of a better balancing of the vertical forces and the rocking moments of the engines, to change the position of the cranks and to increase the weight of single reciprocating parts without at the same time correspondingly changing the distribution of steam; for the degree of uniformity of stress on the shafts $\frac{T \text{ maximum}}{T \text{ minimum}}$ is thereby increased from 3.032 to 4.275, and made worse by 41 per cent. At the same time the temperature ranges became less uniform, $\frac{t_3}{t_1} = 2.14$, versus 1.32, and the "ability to handle" the engine was so faulty that the boat with the Schlick engine could not be used in squadron evolutions, and had once more to get a shaft with cranks at right angles. Furthermore, the end sought—to reduce the vibrations of the hull by counterbalancing the free vertical forces and the rocking moments—was not obtained; on the contrary, the vibrations were much greater.

It is to be observed that the pressure on the reciprocating parts of the four cylinders of the Schlick engine is considerably more uniform than that of the engine with cranks at right angles. $\left(\frac{b}{a} = 1.93, \text{ against } 3.06.\right)$

The four three-cylinder engines of the large war vessels examined show prominently the influence of the cylinder ratios upon the uniformity of the tangential pressures and the temperature ranges.

The smaller the diameter of the H.P. cylinder is in relation to the L.P. cylinder the more uniform are the tangential pressures and the temperature ranges. The proportionally great lack of uniformity of the tangential pressure of the *Kaiser Friedrich III* on her trial trip is caused by the unequal distribution of work in the three cylinders. By increasing the steam admission in the L.P. cylinders, the work in the L.P. cylinders would have become less and that of the I.P. cylinders more, thereby causing the tangential pressures to be more uniform.

The pressure on the rods of the *Kaiser Friedrich III* is reasonably uniform; the temperature ranges are also favorable. Both would, however, be much improved if the distribution of work were made more uniform.

TABLE I.—THREE-CYLINDER ENGINES.

Name of ship.	Cylinder ratios. L.P. cyl. / H.P. cyl.	I.H.P. Maximum / Minimum.	Temp'ture ranges. Maximum / Minimum.	Tangential pressures. Maximum / Minimum.	Pressure on rods. Maximum / Minimum.
Iltis	5.70	1.98	1.64	1.807	1.77
Kaiser Friedrich III	6.24	1.78	1.42	1.957	1.39
Baiern	6.50	1.65	1.31	1.715	1.87
Kaiserin Augusta	6.52	1.30	1.30	1.550	1.75

The influence of the cylinder ratios upon the uniformity of the tangential pressures and the temperature ranges is also noticeable in the four-cylinder engines, but is affected to a considerable degree by the crank angles and the crank sequences.

TABLE II.—FOUR-CYLINDER ENGINES.

Name of ship.	Cylinder ratios. Vol. L.P. cyl. / Vol. H.P. cyl.	I.H.P. Maximum / Minimum.	Temp'ture ranges. Maximum / Minimum.	Tangential pressures. Maximum / Minimum.	Pressure on the rods. Maximum / Minimum.
Hertha	5.10	1.71	1.51	2.300	2.52
Vineta	5.59	1.72	1.81	2.209	2.60
Victoria Louise	5.76	1.81	1.24	2.570	2.31
Baden	5.88	1.57	1.56	1.680	1.90
Wurtemberg	5.88	1.81	1.28	1.720	2.60
North Lyell	6.78	1.78	1.07	1.529	3.05

The crank sequence on the *Baden* and *Wurtemberg* is

On the *Vineta* however it is Since in these engines the two low-pressure cylinders together do considerably less work than the H.P. and I.P. cylinders together, the crank positions of the *Vineta*, where the cranks of the L.P. cylinders are opposite to each other, result in larger maximum and smaller minimum tangential pressures than those of the *Baden* and *Wurtemberg*, when the crank of one L.P. cylinder, that is doing less work, is placed opposite to that of a H.P. or I.P. cylinder, that does more work. Assuming now that the indicator diagrams would be the same if we were to change the crank positions—a proposition that is not quite correct, but approximately so—and moving the curves of the tangential pressures of the various cylinders in the diagram of tangential pressure for the *Baden* in accordance with a crank sequence similar to that of the *Vineta*, as has been done on plate 15, we obtain a ratio of tangential pressures $\frac{\text{maximum}}{\text{minimum}}$ of 2.42 and of $\frac{\text{maximum}}{\text{mean}}$ of 1.50 instead of 1.68 and 1.30 respectively. This diagram, then, also shows in the same manner as that of the *Vineta* the characteristic form of the minima formed by the pair of L.P. cylinders on one side doing little work and the maxima formed by the H.P. and I.P. cylinders on the opposite side doing much work. An approximately uniform distribution of work between the four cylinders would also result in a more uniform stress of the shaft. But as this is most difficult to obtain with four-cylinder triple-expansion engines, it is recommended, in view of the influence upon the stresses on the shaft, to choose a crank sequence similar to that of the *Baden* and *Wurtemberg*.

Against this, however, the vertical forces and the rocking moments on the *Vineta*, due to the position of the cranks of the L.P. cylinder on one side against those of the H.P. and I.P. cylinders on the opposite side, become much smaller under the chosen arrangement of cylinders and the existing weights of the

moving parts than those corresponding to a crank sequence similar to that of the *Baden* and *Wurtemberg*. As graphically demonstrated on plate 15, a change in the crank sequence of the engine of the *Baden* after the pattern of the *Vineta* would reduce the largest free vertical force from 2,113 kilograms to 1,358 kilograms and the largest rocking moment from 53,400 mkg. to 24,140 mkg.

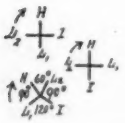
It is a fact that on the *Baden* and *Wurtemberg* the larger rocking moments have not been noticeable; but on other vessels it has been the case. Of the two English armored cruisers *Terrible* and *Powerful*, having engines in all other respects equal, the former vessel had a crank sequence similar to that of the *Baden*, the latter one similar to the *Vineta*. At sea, the vibrations set up in the former were so great that subsequently the same sequence of cranks was adopted as in the *Powerful*, *i. e.*, the two L.P. cranks were placed opposite to each other and at right angles to the H.P. and I.P. Later on, in order to still further reduce vibration, another arrangement of cranks, similar to Schlick's, was adopted on both ships. The result was much worse handling of engines, but a reduction of the rocking moments and in vibration, as shown in the table previously referred to.

The two engines of the German cruisers having the Schlick system here examined were once changed by placing the cranks of the L.P. cylinders opposite to the H.P. and I.P. cylinders—approximately, but not quite diametrically opposite. On the *Hertha* and the *Victoria Louise* the L.P. cranks were thus placed opposite each other. In both cases the tangential pressures were less uniform than in engines with cranks at right angles, but even here the greater lack of uniformity is found in the *Victoria Louise* in which the cranks of the L.P. cylinders are opposite to one another. To be sure, the smallest crank angle on the *Victoria Louise* (42 degrees) is smaller than that of the *Hertha* (52.5 degrees). In addition, in the *Victoria Louise* the engines handled very badly. On the other hand, the temperature ranges and the pressures on the rod are proportionally uniform in the two Schlick engines. It should be noticed here that

though the engines of the *Hertha* handle well and are well balanced without having heavy weights placed in their pistons, that the engines were built very long. Taking the diameter of the L.P. cylinder as unit, the length of the engines on the *Hertha* measure from center to center of the outer cylinders 4.44 diameters against from 3.25 to 3.39 diameters on the other four-cylinder engines of war ships here investigated.

The placing of counterweights on the cranks of the two outer cylinders could not be avoided, as the reciprocating parts were not to be made of different dimensions.

TABLE III.

Crank sequence.	Calculated maxima of unbalanced force couple.	Magnitude of the observed vertical vibrations.	
		One engine in operation.	Two engines in operation.
	1	39.37 millimeters.	Not observed.
	0.64	20.32 millimeters.	43.18 millimeters.
	0.35	Not observed.	Not observed.

NOTE—Direction of rotation indicated by the pointer.

(1.) The difficulties that have thus been shown to exist, when it is attempted to combine the balancing of the vertical forces and the rocking moments with a fair degree of uniformity of the stresses on the shafts, have been very much avoided by the skillful arrangements of the more recent Schlick engines, as may be seen from plate 13, in the S. S. *North Lyell.* The cranks of the L.P. cylinders that are doing less work are placed opposite to the cranks of the H.P. and I.P. cylinders that do more work. The smallest crank angle is increased to 65 degrees, and the angle of action—that is the smallest crank angle into which all the cranks may be brought together by the transposition of one or more cranks by 180 degrees—is made 107 degrees, against 90 degrees as in the *Hertha* and the *Victoria Louise.* This is advantageous,

as the degree of uniformity increases with this angle (see "Zeitschrift," 1899, No. 1222). Furthermore, the smallest angle is formed by the cranks of the L.P. cylinders, so that the lesser work of these two cylinders is added together in the diagram of tangential pressures, while in the *Hertha* and *Victoria Louise* the larger work of the other two cylinders, the H.P. and I.P., is added together; finally, the two L.P. cylinders are placed at the end of the engines, and the reciprocating parts are made lighter in accordance with the lesser work of these cylinders. In this manner an extraordinarily high degree of uniformity of turning has been obtained, combined with a good result of balancing.

(2.) For warships this arrangement would be objectionable on account of the great length of the engine (4.24 diameters), the different scantlings of the reciprocating parts, the complication of the piping caused by placing the L.P. cylinders at the extreme ends of the engine, and because the total weight of the engine would be increased. For merchant ships, however, this arrangement appears to be worthy of imitation, the more so since the temperature ranges have become equally uniform with the tangential pressures. A good balancing of the free forces and the rocking moments is always to be recommended, when such advantages of a marine engine can be obtained without any great disadvantages, and as long as it cannot be ascertained beforehand whether such forces and moments will produce vibrations in the ship under consideration.

(3.) If these crank and cylinder positions, that proved effective in the *North Lyell*, had been used in the engines of the same length as those of the great cruiser *Hertha*, the tangential pressures would have been much more uniform here also, as is shown in the diagram of tangential pressures on plate 16. In the construction of this diagram it was again assumed, though not quite correctly, that the indicator diagrams of the various cylinders would remain the same when the cranks were placed opposite each other. The diagrams of the acceleration pressures have been changed in accordance with the changed weights; thus they were chosen, as much as permissible, without obtaining impracticable dimensions, so that a complete balancing of the free

vertical forces and the working moments became possible with the assumed crank sequence and cylinder positions.

(4.) By transposing the diagrams of the tangential pressures obtained from the separate cylinders in accordance with the changed crank sequence, a diagram of the total tangential pressure of the crank shaft is obtained, which shows that the ratio $\frac{T \text{ maximum}}{T \text{ minimum}}$ of 2.30 could be improved to 1.171, and the ratio $\frac{T \text{ maximum}}{T \text{ mean}}$ from 1.42 to 1.27, provided it had been found expedient to take the less comfortable position of the cylinders into the bargain.

(5.) In conclusion, we give the data of a more recent quadruple-expansion engine which has been balanced according to Schlick and that has in every respect given good proportions without being built especially long. The possibility of getting a good distribution of the work between the four cylinders made it easier to obtain more uniform tangential pressures. The work of the second L.P. cylinder is nearly one and one-half times larger than that of each of the other three cylinders, and thereby reasonably uniform temperature ranges and rod pressures were obtained in the four cylinders.

(6.) An equal distribution of work between the four cylinders would have made the pressures of the moving parts more unequal in this case. The tangential pressures and the temperature ranges are not as uniform as in the triple-expansion engines of *North Lyell;* against this, however, the pressures of the moving parts are considerably more uniform. The compromise between the various constructional proportions, tangential pressures, temperature ranges and rod pressures has been accomplished best in the quadruple-expansion engine with four cylinders of the *Patricia* by the balancing of the free vertical forces and the rocking moments.

(7.) In this investigation it has been emphasized to obtain small differences between the maxima and minima values of the tangential pressures on the crank shaft, that the changes in the torque of the shafting line might be as small as possible. The

influence of the amount of the tangential pressure on the torsion of the shaft is shown by the following observation:

(8.) The angular velocity of the crank shaft is dependent on the tangential pressure and the resistance which the turning moment meets in the screw shaft. With a constant tangential pressure the angular velocity of the crank shaft becomes slower with an increase in the resistance of the screw, which takes place, for instance, when a greater pitch is used; and the engine turns faster with the same steam pressure when a smaller pitch is used and thereby the resistance of the screw is decreased.

(9.) With a constant resistance of the screw shaft the angular velocity of the crank shaft would increase or decrease according to the tangential pressure acting on it, which would be in accordance with its turning moments; *i. e.*, these turning moments would always be transmitted to the screw shaft. The resistance which the crank shaft meets in the screw shaft changes continuously, and therefore the angular velocity of the crank shaft does not change in the same degree as the tangential pressure, although the turning moment of the crank shaft caused by the tangential pressure produces its full effect.

(10.) The mean twisting moment transmitted to the screw from the crank shaft is equal to the moment which the resistance of the ship exerts during a uniform forward movement of the ship. When the turning moment of the crank shaft increases beyond its mean value the angular velocity of the crank shaft increases with it. The entire turning moment will not be transmitted, however, to the screw and utilized to overcome the resistance of the ship, but a portion of the turning moment exerted by the crank shaft is used to overcome the inertia moments of the crank shaft and the screw. The total twist of the screw shaft corresponding to the magnitude of the largest turning moment of the crank shaft therefore takes place only right abaft of the after crank, but the twist of the screw shaft towards the screw, while also becoming greater than its mean twist, still increases less than in the vicinity of the crank shaft. If, then, the tangential pressure at the screw shaft is diminished and becomes less than the mean, the angular velocity of the crank shaft becomes slower

and the turning moment transmitted to the screw by the crank shaft will be smaller.

(11.) But the inertia of the masses of the screw shaft and the screw exert their influence now and cause a turning moment in the same way as the turning moment of the crank shaft, so that the smallest twist of the screw shaft corresponds to the smallest turning transmitted by the crank shaft to the screw shaft only close to the crank shaft; but away towards the screw it becomes greater.

(12.) Therefore the variation in the torsion of the shaft immediately abaft of the last crank is directly dependent upon the ratio of the greatest and smallest tangential pressure $\frac{T\,\text{maximum}}{T\,\text{minimum}}$, while these variations gradually decrease in the direction of the screw on account of the equalizing action of the masses of the screw shaft and the screw, and the torsion of the screw shaft near the screw becomes approximately constant. Hence the total twist of a screw shaft is dependent upon the masses of the screw shaft and the screw, and the variations in the work transmitted to the screw shaft by the crank shaft. But the greatest variation that takes place in the torsion of the screw shaft is only dependent upon the variations of the turning moments transmitted to the screw shaft by the crank shaft, therefore dependent upon the degree of uniformity of the tangential pressure, and it is this largest amount of twisting that counts, as the screw shafts are made of an equal diameter for their entire length, and are loaded in their middle and after sections not only by torsinal but also by bending stresses.

(13.) The tangential pressure, however, acting at any moment upon the crank shaft is only indicated approximately by the diagram of tangential pressures; for this diagram has been constructed on the assumption of a uniform angular velocity of the crank shaft, therefore disregarding the influence of the rotating masses of the crank shaft upon the tangential pressure. To this mass should be added about one-half of the mass of the connecting rods. This mass has to be accelerated by the increase in the angular velocity of the crank shaft by the increasing tan-

gential pressure given in the diagram, and the force required for this purpose must be deducted from the tangential pressure. The greatest tangential pressure acting upon the crank shaft will therefore be a little less than that indicated by the diagram.

(14.) In the same manner will the inertia stored up in the crank shaft by the acceleration of the masses become an active driving force when the angular velocity is decreased, and it should be added to the lowest of the tangential pressures indicated in the diagram. With greater variations in the tangential pressure of the crank shaft the variations in the angular velocity of the crank shaft will become greater with an engine of a given size, and consequently the equalizing effect of the masses of the crank shaft become a little more important.

(15.) The forces required for the increased or decreased acceleration of the masses of the crank shaft are, however, so small in proportion to the tangential pressures of the diagram, that they may be neglected in estimating the influence shown by this diagram upon the variations in the torsion of the shaft.

(16.) The axiom expressed before must therefore be maintained, that a designer of marine engines must endeavor to make the differences in the tangential pressures as small as possible, in order to minimize the stresses in the shaft caused by variations in torque.

(17.) How this is to be effected is best studied from actual engine practice, and for this purpose the publication of the results of these investigations has been undertaken. Should a consideration of these lead others to conclusions differing from those herein contained, it would add to the elucidation of the questions at issue to exchange views on the subject. The material given herewith may only increase in value thereby.

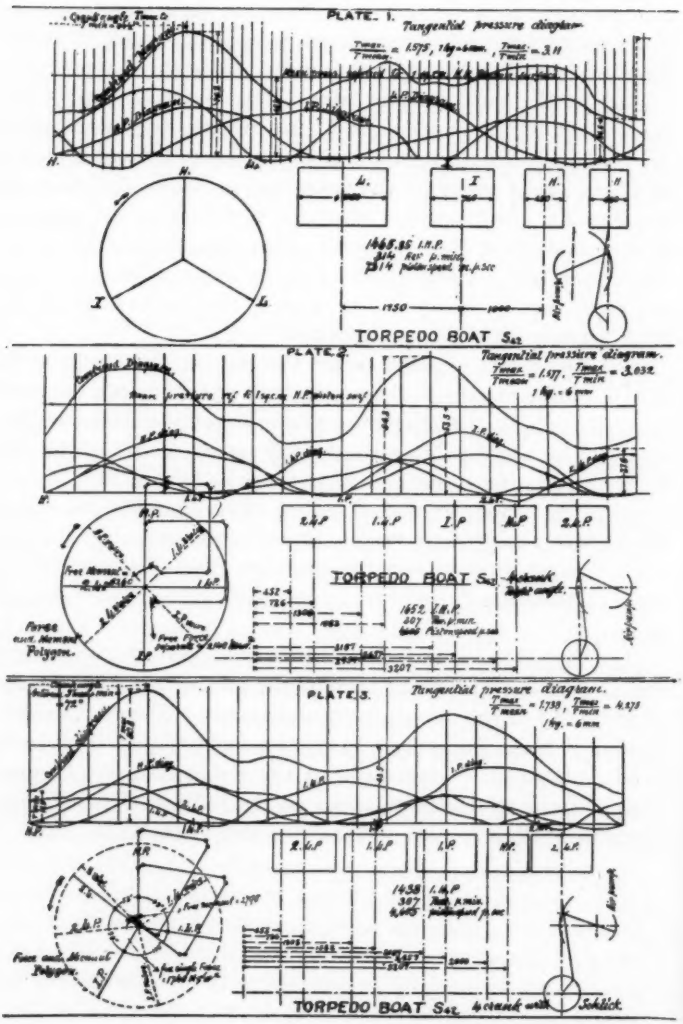


PLATE. 1.
Tangential pressure diagram
1465.85 I.H.P.
TORPEDO BOAT S42
PLATE. 2.
Tangential pressure diagram.
TORPEDO BOAT S..
PLATE. 3.
Tangential pressure diagram.
1458 I.H.P
TORPEDO BOAT S42. 4 crank with Schlick.

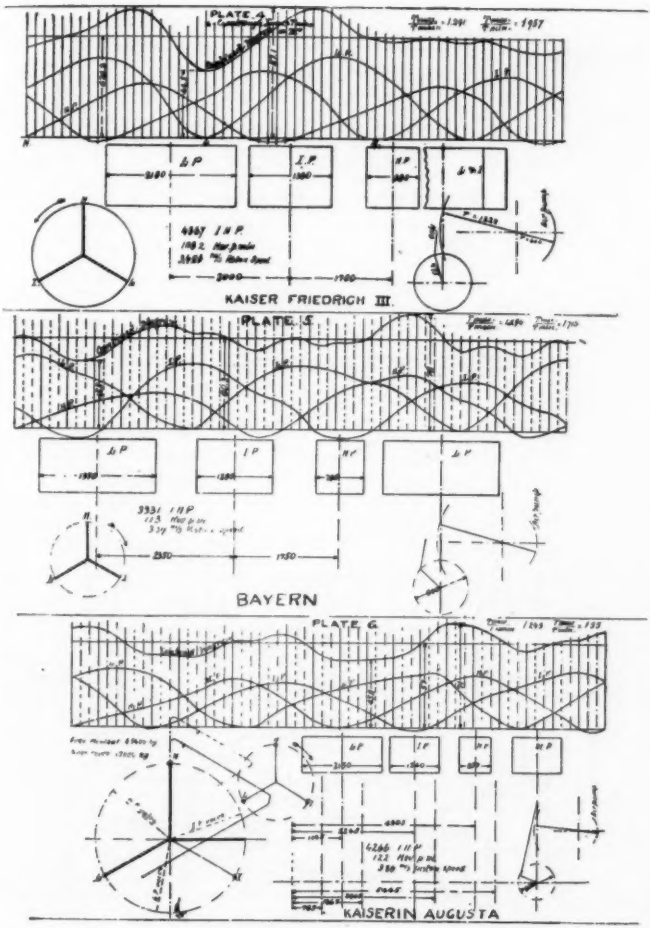


PLATE A
H.P.
I.P.
L.P.
KAISER FRIEDRICH III.
PLATE F
BAYERN
PLATE G
KAISERIN AUGUSTA

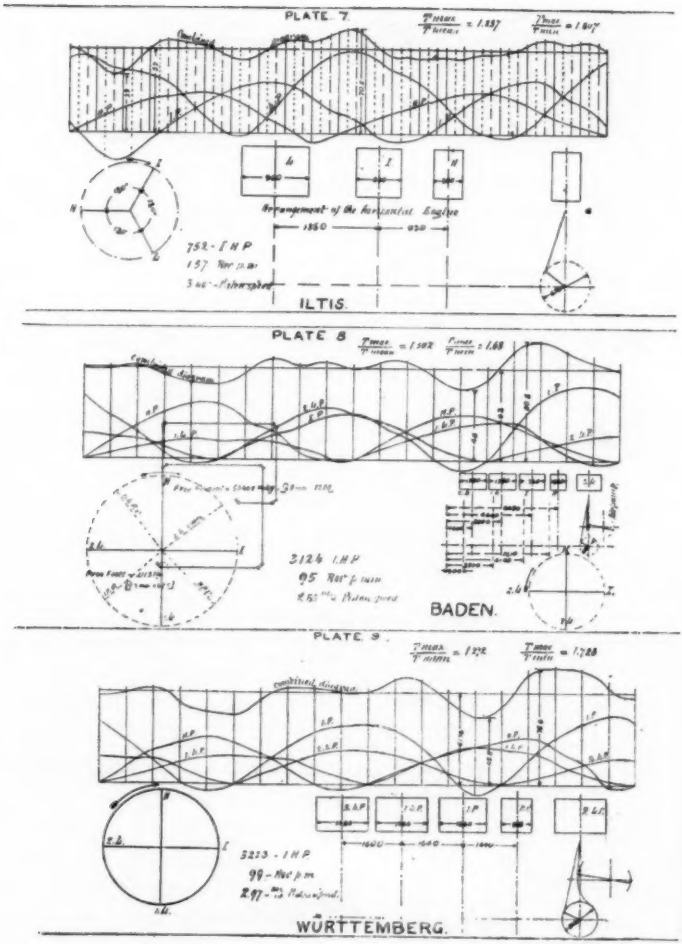


PLATE 7.
Arrangement of the horizontal Engine
752 - I.H.P.
137 Rev. p.m.
ILTIS.
PLATE 8
3124 I.H.P.
95 Rev. p.m.
BADEN.
PLATE 9.
5213 - I.H.P.
99 - Rev. p.m.
WÜRTTEMBERG.

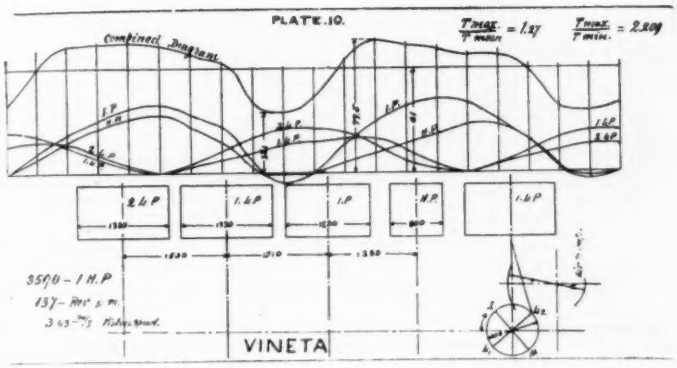


PLATE.10.
Combined Diagram
VINETA

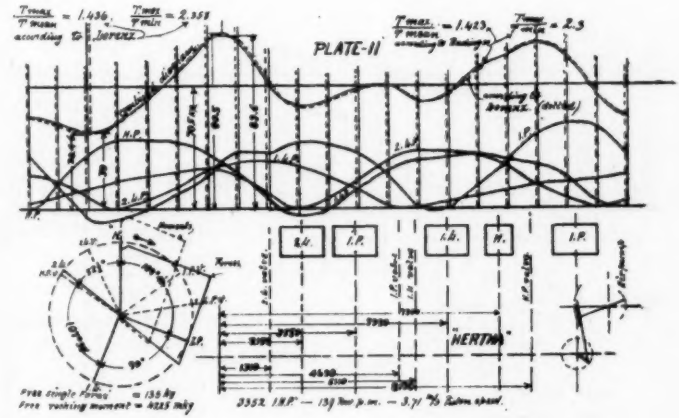


PLATE-11
HERTHA

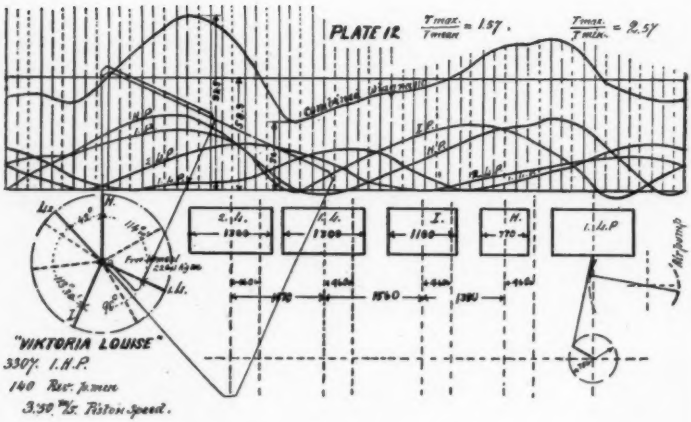


PLATE 12
Tmax./Tmean = 1.57.
Tmax./Tmin. = 2.57
Combined Diagram
H.
I.
L.
2 H.
2 L.
1.H.P
Air pump
"VIKTORIA LOUISE"
3307. I.H.P.
140 Rev. p.min
3.50 m/s. Piston Speed.

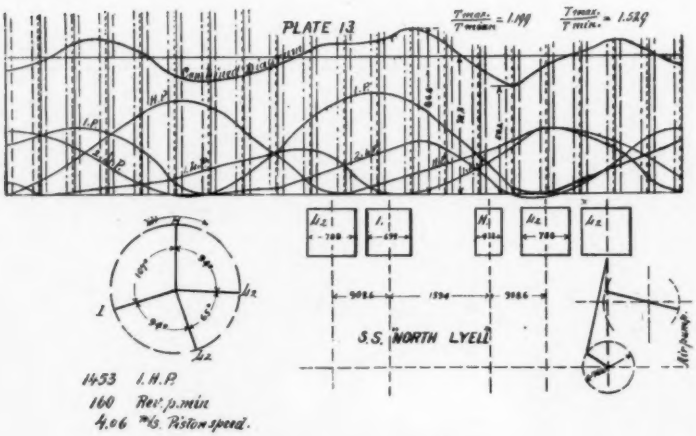
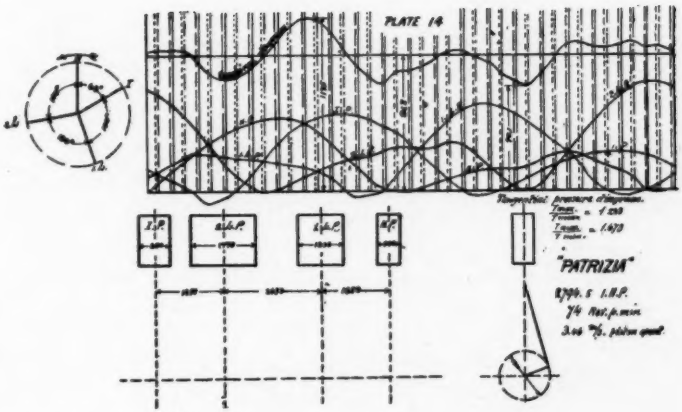
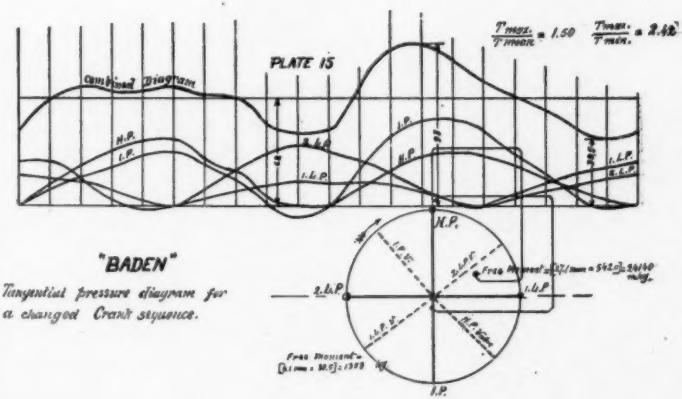
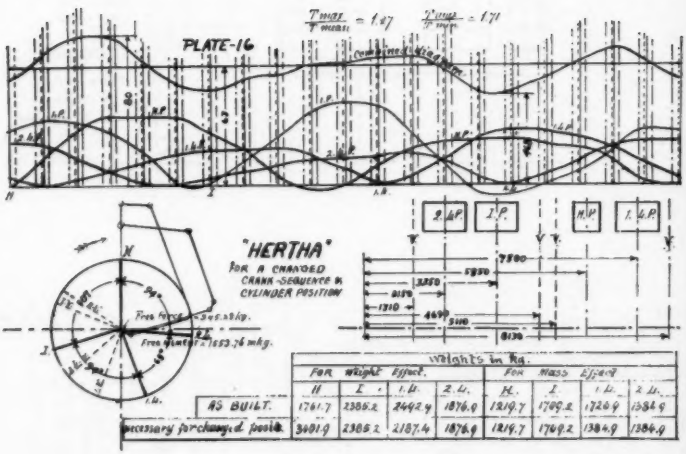


PLATE 13
Tmax./Tmean = 1.99
Tmax./Tmin. = 1.529
Combined Diagram
H.P.
I.P.
L.P.
S.S. "NORTH LYELL"
Air pump
1453 I.H.P.
160 Rev. p.min
4.06 m/s. Piston speed.





Tangential pressure diagram for a changed Crank sequence.



	Weights in Kg.							
	For weight Effect.				For mass Effect			
	II	I.	1. U.	2. U.	H.	I.	1. U.	2. U.
AS BUILT.	1761.7	2388.2	2492.4	1876.9	1219.7	1709.2	1720.9	1384.9
necessary for changed position.	3401.9	2388.2	2187.4	1876.9	1219.7	1749.2	1384.9	1384.9

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Name of ship.	Number of expansions.	Number of cylinders.	Number of engines.	Crank-sequence.	I.H.P.	Revolutions per minute.	Stroke, mm.	Diameters of cylinders. mm.				Mean piston areas, square centimeter.				Cylinder (from mean ton area		
								H	I	L_1	L_2	H	I	L_1	L_2	H	I	L
S-42. Three-cranks,	3	3	1		1466	314	460	480	760	1080	...	1779	4506	9130	...	1	2.53	5.
S-42. Four-cranks, at right angles,	3	4	1		1652	307	450	500	730	760	760	1924	4146	4497	4497	1	2.16	4.
S-42. Four-cranks, Schlick system	3	4	1		1438	307	450	500	730	760	760	1924	4146	4497	4497	1	2.16	4.
Kaiser Friedrich III	3	3	3		4867	108.2	950	880	1380	2180	...	5968	14843	37211	...	1	2.49	6.
Bayern	3	3	2		3331	113	900	780	1280	1970	...	4678	12768	30380	...	1	2.73	6.
Kaiserin Augusta,	3	3	3		4266	122	950	850	1340	2150	...	5568	13996	36294	...	1	2.51	6.
Iltis	3	3	2		752	157	650	380	600	900	...	1110.7	2804.1	6334.3	...	1	2.53	5.
Baden	3	4	2		3124	95	900	810	1260	1380	1380	5065	12381	14869	14869	1	2.44	5.
Württemberg	3	4	2		3223	99	900	810	1260	1380	1380	5065	12381	14869	14869	1	2.44	5.
Vineta	3	4	3		3590	137	750	800	1230	1330	1330	4944	11800	13810	13810	1	2.39	5.
Hertha	3	4	3		3352	139	800	730	1160	1160	1160	4115	10498	10498	10498	1	2.55	5.
Victoria Luise	3	4	3		3307	140	750	770	1110	1300	1300	4583	9604.3	13201	13201	1	2.10	5.
North Lyell	3	4	?		1453	160	762	432	699	788	788	1426.5	3798.3	4837.8	4837.8	1	2.66	6.
Patrizia	4	4	2		2794.5	74	1400	585	850	1220	1770	2587.3	5573.9	1154.6	24461.8	1	2.15	4.

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
	Cylinder ratios (from mean piston areas).				Cut-offs (steam admission).				$\frac{r}{L}$	Piston speeds m/s.	$\omega = \frac{\pi n}{30}$	$r\omega^2$	Weights of reciprocating parts. kg.				
	H	I	L_1	L_2	H	I	L_1	L_2					H	I	L_1	L_2	H
	1	2.53	5.13	...	?	?	0.6	...	1 : 4.782	4.814	32.9	249.0	419.7	497.5	600.6	...	278.1
	1	2.16	4.67	...	0.45	0.45	0.45	0.45	1 : 4.489	4.605	32.15	232.4	368.2	427.6	437.3	417.9	243.2
	1	2.16	4.67	...	0.45	0.45	0.45	0.45	1 : 4.489	4.605	32.15	232.4	348.3	492.1	487.1	350.4	243.2
	1	2.49	6.24	...	0.65	0.65	0.6	...	1 : 4.105	3.426	11.33	60.975	4593.9	5067.9	6173.9	...	2740.8
	1	2.73	6.50	...	0.67	0.50	0.45	...	1 : 4.56	3.39	11.83	63.0	3016	3351	3904	...	1673
	1	2.51	6.52	...	0.67	0.65	0.55	...	1 : 4	3.86	12.78	77.5	3210	3614	4761	...	2178
	1	2.53	5.70	...	0.70	0.50	0.40	...	1 : 4.615	3.407	16.44	87.838	...	...	...	...	302.2
)	1	2.44	5.88	...	0.63	0.58	0.42	0.45	1 : 4.44	2.85	9.94	44.5	2731	3086	3198	3207.5	1553
)	1	2.44	5.88	...	0.617	0.58	0.45	0.45	1 : 4.44	2.97	10.367	48.364	2731	3086	3198	3207.5	1553
)	1	2.39	5.59	...	0.64	0.60	0.40	0.40	1 : 4.35	3.43	14.36	77.329	1821	2138.	2168	2163	1175
3	1	2.55	5.10	...	0.74	0.63	0.42	0.45	1 : 4	3.71	14.53	84.4	1761.7	2385.2	2492 9	1876.9	1219.7
	1	2.10	5.76	...	?	?	?	?	1 : 4.27	3.50	14.66	80.7	1920.7	2457.8	2450.5	1871.3	1088.6
.8	1	2.66	6.78	...	?	?	?	?	1 : 4	4.06	16.79	107.4	1214.7	1346.5	1038.6	1080.7	576.4
.8	1	2.15	4.46	9.46	?	?	?	?	1 : 4.29	3.46	7.75	42.044	4350	4508	5766	6226	1760

* 18 in the boilers; 13 in the

	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
	Piston speeds m/s.	$\omega = \frac{\pi n}{30}$	$r\omega^2$	Weights of reciprocating parts. kg.				Inertia weights. kg.				Length of engine between extreme cylinder centers divided by diameter of L.P. cylinder.	Boiler pressure, designed. Pressure above atmosphere. kg.	Steam pressure in H.P. cylinder by indicated diagrams. Pressure above atmosphere. kg.	Indicated horse p		
				H	I	L_1	L_2	H	I	L_1	L_2				H	I	L_1
2	4.814	32.9	249.0	419.7	497.5	600.6	...	278.1	319.6	412.9	...	**2.27**	13	12.66	427	505	534
9	4.605	32.15	232.4	368.2	427.6	437.3	417.9	243.2	300.2	306.2	340.7	**3.26**	15	13.25	462	512	332
9	4.605	32.15	232.4	348.3	492.1	487.1	350.4	243.2	364 7	356.2	379.3	**3.26**	15	12.60	358	451	330
5	3.426	11.33	60.975	4593.9	5067.9	6173.9	...	2740.8	3414.8	5383.6	...	**1.70**	12	11.33	1186	1573	2108
	3.39	11.83	63.0	3016	3351	3904	...	1673	1945	2648	...	**2.08**	12	12.44	882	993	1456
	3.86	12.78	77.5	3210	3614	4761	...	2178	2742	3869	...	**1.66**	12	10.41	1233	1427	1606
5	3.407	16.44	87.838	...	...	...	...	302.25	365	499.8	...	**2.56**	13	12.07	188	191	373
	2.85	9.94	44.5	2731	3086	3198	3207.5	1553	1908	2020	2127.1	**3.39**	13	10.99	803	988	627
	2.97	10.367	48.364	2731	3086	3198	3207.5	1553	1908	2020	2127.1	**3.39**	13	11.8	808	1132	659
5	3.43	14.36	77.329	1821	2138	2168	2163	1175	1492	1522	1629	**3.25**	13	12.37	859	1261	738
	3.71	14.53	84.4	1761.7	2385.2	2492 9	1876.9	1219.7	1709.2	1726.9	1384.9	**4.44**	*	13.18	976	1032	742
7	3.50	14.66	80.7	1920.7	2457.8	2450.5	1871.3	1088.6	1581.7	1723.2	1101.8	**3.34**	13	13.03	1082	1008	597
	4.06	16.79	107.4	1214.7	1346.5	1038.6	1080.7	576.45	708.25	572.4	707.5	**4.34**	...	11.52	434	478	272
9	3.46	7.75	42.044	4350	4508	5766	6226	1760	1918	3056	3516	**3.58**	...	14.24	607.9	625.8	661

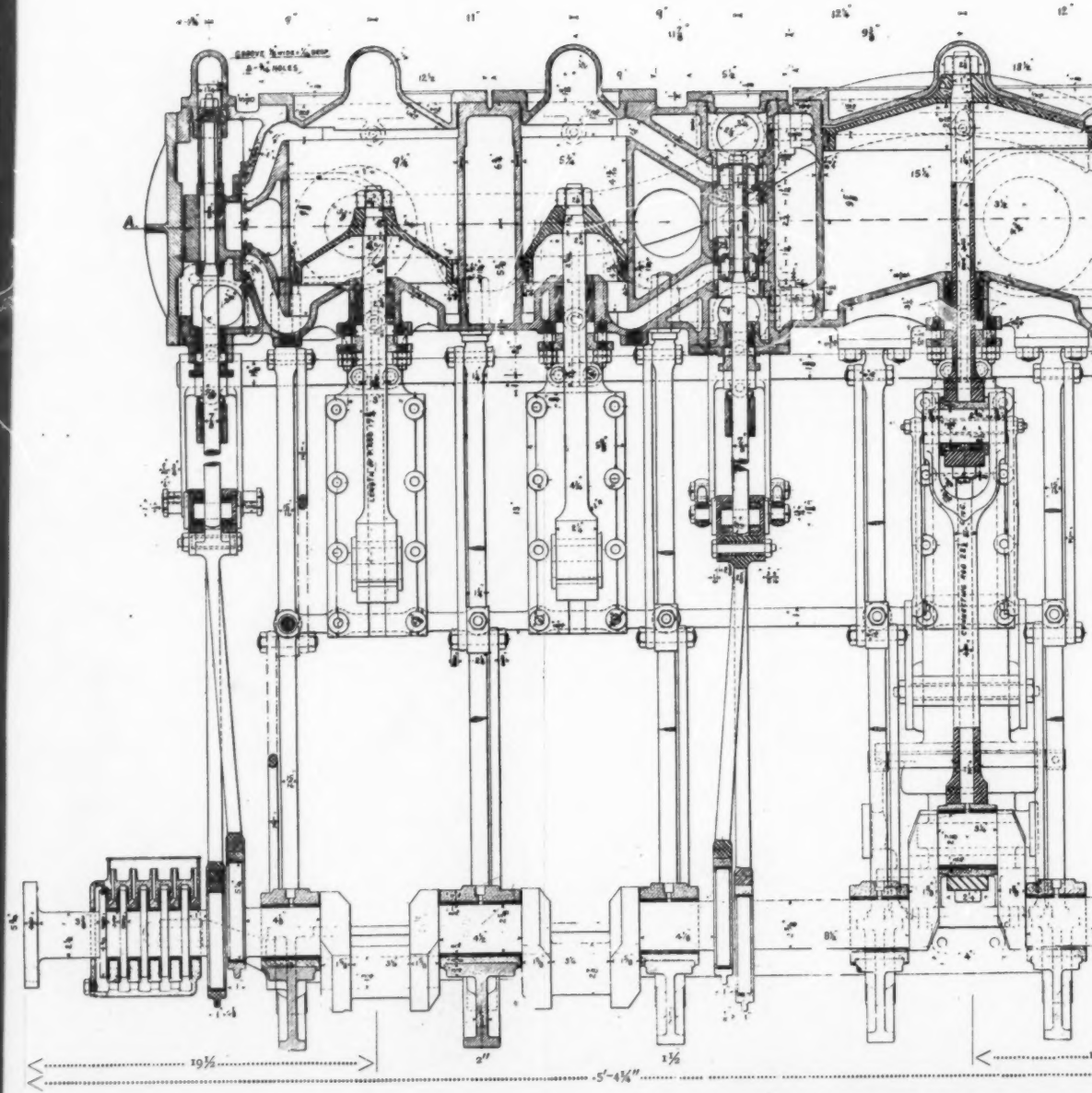
* 18 in the boilers; 13 in the H.P. valve chest.

	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	
	ndicated horse power.			Max. / Min. I.H.P. of the cylinders.	Tangential pressure.		Pressures on the piston, including acceleration of the moving parts.				Max. / Min. of greatest pressures of moving parts of each cylinder.	Temperature ranges. Centigrade.				
	I	L_1	L_2		Max. / Min.	Max. / Mean.	a H	b I	c L_1	d L_2		t_1 H	t_2 I	t_3 L_1	t_4 L_2	
	505	534	...	1.25	**3.110**	1.575	11.884	16.132	11.413	...	**1.41**	35.5	36.8	25.2	...	1
	512	332	346	1.54	**3.032**	1.577	11.505	14.739	6.525	4.812	**3.06**	29.6	36.5	39.2	...	1
	451	330	299	1.51	**4.275**	1.738	8.754	14.988	9.174	7.766	**1.93**	24.0	35.5	51.5	...	2
	1573	2108	...	1.78	**1.957**	1.291	42.313	48.789	58.793	...	**1.89**	37.1	32.0	45.5	...	1
	993	1456	...	1.65	**1.715**	1.294	30.430	56.856	55.018	...	**1.87**	32.6	38.4	42.6	...	1
	1427	1606	...	1.30	**1.550**	1.245	31.320	54.752	50.630	...	**1.75**	27.8	32.9	36.1	...	1
	191	373	...	1.98	**1.807**	1.237	6.977	10.571	12.327	...	**1.77**	28.54	31.3	46.8	...	1
	988	627	706	1.57	**1.680**	1.302	27.645	37.805	19.924	21.114	**1.90**	30.0	34.4	46.7	...	1
	1132	659	624	1.81	**1.728**	1.272	33.824	50.143	19.255	21.381	**2.60**	31.7	34.8	40.6	...	1
	1261	738	732	1.72	**2.209**	1.270	26.376	47.719	18.367	23.339	**2.60**	23.5	36.3	42.6	...	1
	1032	742	602	1.71	**2.300**	1.423	37.076	33.615	15.222	14.729	**2.52**	42.3	30.9	46.6	...	1
	1008	597	620	1.81	**2.570**	1.570	25.284	34.345	14.851	18.547	**2.31**	28.5	29.1	35.2	...	1
	478	272	269	1.78	**1.529**	1.199	9.472	15.481	5.077	5.370	**3.05**	33.3	31.6	33.8	...	1
9	625.8	661.4	899.4	1.48	**1.678**	1.288	18.836	22.686	25.979	20.230	**1.88**	31.5	30.7	36.3	37.6	1

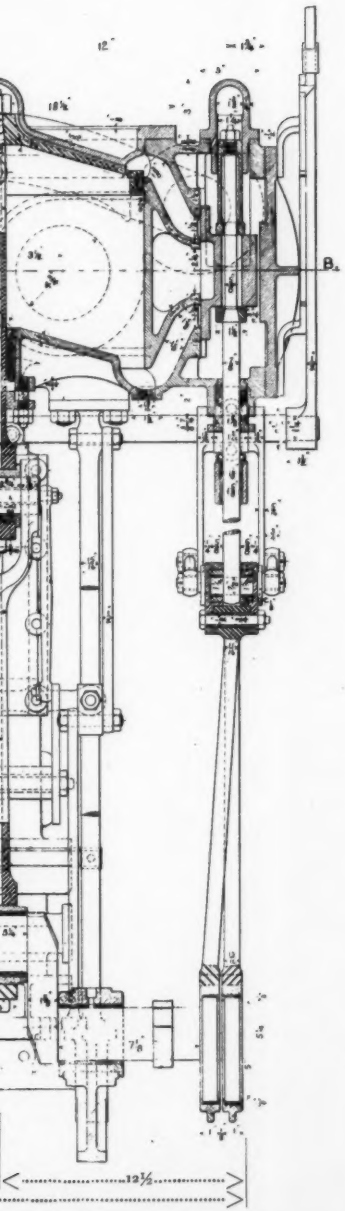
34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Inertia weights. kg.			Length of engine between extreme cylinder centers divided by diameter of L.P. cylinder.	Boiler pressure, designed. Pressure above atmosphere. kg.	Steam pressure in H.P. cylinder by indicated diagrams. Pressure above atmosphere. kg.	Indicated horse power.				$\frac{\text{Max.}}{\text{Min.}}$ I.H.P. of the cylinders.	Tangential pressure.		Pressures on the piston, including acceleration of the moving parts.			
I	L_1	L_2				H	I	L_1	L_2		$\frac{\text{Max.}}{\text{Min.}}$	$\frac{\text{Max.}}{\text{Mean.}}$	a H	b I	c L_1	d L_2
319.6	412.9	...	**2.27**	13	12.66	427	505	534	...	1.25	**3.110**	1.575	11.884	16.132	11.413	...
300.2	306.2	340.7	**3.26**	15	13.25	462	512	332	346	1.54	**3.032**	1.577	11.505	14.739	6.525	4.81
364 7	356.2	379.3	**3.26**	15	12.60	358	451	330	299	1.51	**4.275**	1.738	8.754	14.988	9.174	7.76
3414.8	5383.6	...	**1.70**	12	11.33	1186	1573	2108	...	1.78	**1.957**	1.291	42.313	48.789	58.793	...
1945	2648	...	**2.08**	12	12.44	882	993	1456	...	1.65	**1.715**	1.294	30.430	56.856	55.018	...
2742	3869	...	**1.66**	12	10.41	1233	1427	1606	...	1.30	**1.550**	1.245	31.320	54.752	50.630	...
365	499.8	...	**2.56**	13	12.07	188	191	373	...	1.98	**1.807**	1.237	6.977	10.571	12.327	...
1908	2020	2127.1	**3.39**	13	10.99	803	988	627	706	1.57	**1.680**	1.302	27.645	37.805	19.924	21.11
1908	2020	2127.1	**3.39**	13	11.8	808	1132	659	624	1.81	**1.728**	1.272	33.824	50.143	19.255	21.38
1492	1522	1629	**3.25**	13	12.37	859	1261	738	732	1.72	**2.209**	1.270	26.376	47.719	18.367	23.33
1709.2	1726.9	1384.9	**4.44**	*	13.18	976	1032	742	602	1.71	**2.300**	1.423	37.076	33.615	15.222	14.72
1581.7	1723.2	1101.8	**3.34**	13	13.03	1082	1008	597	620	1.81	**2.570**	1.570	25.284	34.345	14.851	18.54
708.25	572.4	707.5	**4.34**	...	11.52	434	478	272	269	1.78	**1.529**	1.199	9.472	15.481	5.077	5.37
1918	3056	3516	**3.58**	...	14.24	607.9	625.8	661.4	899.4	1.48	**1.678**	1.288	18.836	22.686	25.979	20.23

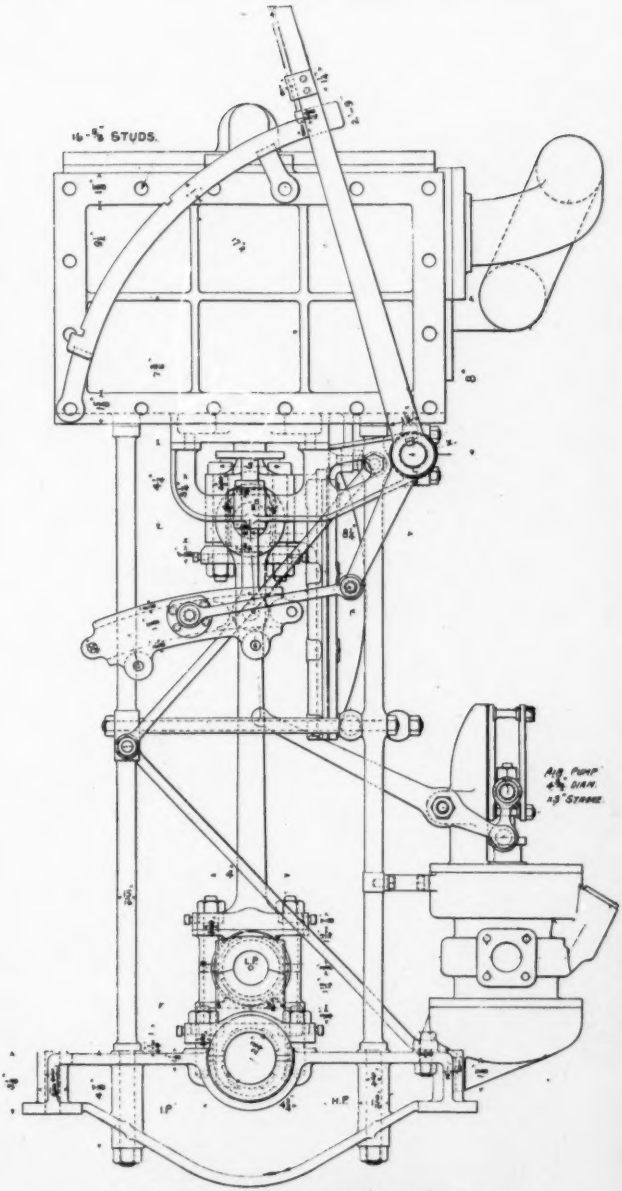
.P. valve chest.

	49	50	51	52	53	54	55	56	57	58	59	60
	the piston, inceleration of the rts.		Max. / Min. of greatest pressures of moving parts of each cylinder.	Temperature ranges. Centigrade.				Temperature ranges, Max. / Min.	Steam jackets.	Name— / of builder.	Place—	Name of the ship.
	c L_1	d L_2		t_1 H	t_2 I	t_3 L_1	t_4 L_2					
2	11.413	...	**1.41**	35.5	36.8	25.2	...	**1.46**	...	Schichau.	Elbing.	*S-42.* Three-cranks.
0	6.525	4.812	**3.06**	29.6	36.5	39.2	...	**1.32**	...	Germania.	Tegel.	*S-42.* Four-cranks, at right angles.
3	9.174	7.766	**1.93**	24.0	35.5	51.5	...	**2.14**	...	Germania.	Tegel.	*S-42.* Four-cranks Schlick system
0	58.793	...	**1.39**	37.1	32.0	45.5	...	**1.42**	...	Kais. Werft.	Wilhelmshaven.	*Kaiser Friedrich III.*
5	55.018	...	**1.87**	32.6	38.4	42.6	...	**1.31**	I	Schichau.	Elbing.	*Bayern.*
2	50.630	...	**1.75**	27.8	32.9	36.1	...	**1.30**	...	Germania.	Tegel.	*Kaiserin Augusta.*
7	12.327	...	**1.77**	28.54	31.3	46.8	...	**1.64**	...	Schichau.	Elbing.	*Iltis.*
5	19.924	21.114	**1.90**	30.0	34.4	46.7	...	**1.56**	...	Germania.	Tegel.	*Baden.*
5	19.255	21.381	**2.60**	31.7	34.8	40.6	...	**1.28**	...	Kais. Werft.	Wilhelmshaven.	*Württemberg.*
0	18.367	23.339	**2.60**	23.5	36.3	42.6	...	**1.81**	...	Kais. Werft.	Danzig.	*Vineta.*
5	15.222	14.729	**2.52**	42.3	30.9	46.6	...	**1.51** H I L_1 L_2		Vulcan.	Stettin.	*Hertha.*
3	14.851	18.547	**2.31**	28.5	29.1	35.2	...	**1.24**	...	Weser.	Bremen.	*Victoria Luise.*
	5.077	5.370	**3.05**	33.3	31.6	33.8	...	**1.07**	?	?	England.	*North Lyelt.*
9	25.979	20.230	**1.88**	31.5	30.7	36.3	37.6	**1.23**	?	Vulcan.	Stettin.	*Patrizia.*



50-FOOT CUTTER, ENGINE TY





Cylinders, $\frac{5\frac{3}{4} \text{ inches by } 9\frac{1}{4} \text{ inches by } 15\frac{1}{4} \text{ inches}}{9 \text{ inches}}$.

NGINE TYPE Z.

STANDARD STEAM-CUTTER MACHINERY FOR THE U. S. NAVY.

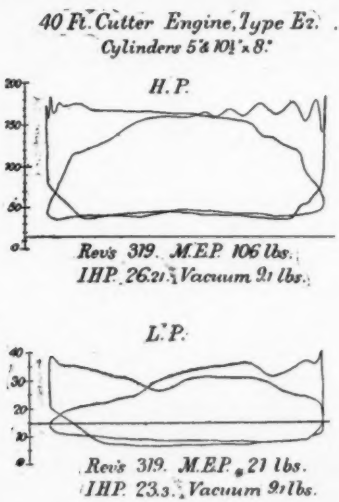
By A. M. P. Maschmeyer, Associate.

The adaptation of standard boats for the U. S. Navy a few years ago compelled the overhauling and redesigning of the machinery of all steam cutters in order to bring them down to certain fixed types. The hulls of these boats are built of white cedar on framings of white oak, copper fastened throughout. They are built in the following sizes, viz: 28, 30, 33, 36, 40 and 50 feet. In all of them the Ward type of boiler is used, and the engines are vertical inverted compounds, excepting the lately added fifty-foot cutter, which is fitted with a triple-expansion engine. All of them have keel condensers and air pumps of the Bailey type. The following table gives the types of engines and boilers used in the various boats:

Size.	Type of Engine.		Ward Boiler.
Feet.		*Inches.*	
28	B_3	$\frac{3\frac{1}{2}+7}{6}$	Round type B, improved.
30	B_3	$\frac{3\frac{1}{2}+7}{6}$	Round type D, improved.
33	G_2	$\frac{4+8}{6}$	Square type D.
36	G_2	$\frac{4+8}{6}$	Square type G_1.
40	E_2	$\frac{5+10\frac{1}{2}}{8}$	Round type G_1.
50	Z	$\frac{5\frac{1}{2}+9\frac{1}{2}+15\frac{1}{2}}{9}$	Square type H_1, impr'd.

The Ward boiler belongs to the class of water-tube boilers having bent and straight tubes. A hollow ring-shaped casting rests upon the ash pan and supports the grate, by means of lugs projecting inwardly. The bent tubes are screwed into bosses of this base ring and support the steam drum centrally above

the grate. The upper ends of these tubes which are bent horizontaly are in different planes, thus leaving openings for the passage of the gases. They are screwed into similar bosses on the lower end of the steam drum, which has on its lower part,

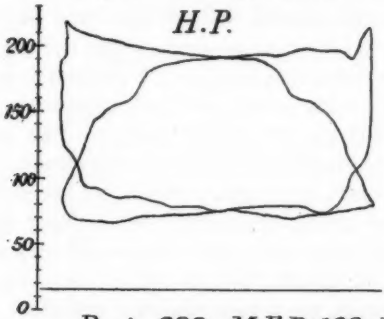


inside, a separating ring, which divides the ascending and descending currents of water. Through the bottom of the steam drum project a number of straight tubes which are closed by caps on their lower ends, and in which, by means of hanging internal tubes, the water is rapidly set into circulation. The bent tubes are all 1¼ inches inside diameter and the straight tubes 1½ inches diameter. A casing lined with asbestos surrounds tubes and drum. The boilers are fitted with pop safety valves, glass water gauges, gauge cocks, check and blow valves, steam jet and whistle. The smoke pipe is removable, by the withdrawal of two pins in its base. For the 28, 30, 33 and 36-foot cutters one feed pump is provided, while the 40 and 50-foot boats have two pumps. The feed tanks, of which there are three for all but the 50-foot cutter, which has five, are placed one under the boiler as a protection against fire and one on each side of the engine.

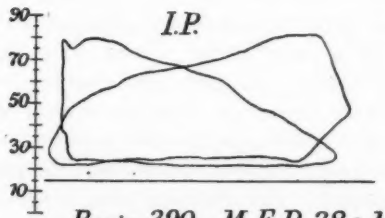
They are all connected by a pipe with each other and with the suction pipe of the feed pump, which by a suitable arrangement of valves can pump directly from any one tank to the boiler. The coal bunkers are placed one on each side of the boiler. The designs of the compound engines used for the 28, 30, 33, 36 and 40-foot cutters are very similar. A bedplate supports in three bearings, the crank shaft, and also carries, by means of two horns at the after end, the thrust bearing. The crank shaft has two cranks at an angle of 90 degrees with each other, two eccentrics for the after valve gear forged on the shaft, an air-pump eccentric, the thrust rings and the coupling disk. The eccentrics for the forward valve gear are forged on only in the type B_3 engine, in the others they are keyed on. The framing is cast of composition, the frames for one cylinder being cast together. The lower parts of each pair are inclined away from each other, giving thus easier access to the connecting rod ends. Two horizontal tie rods brace the frames to each other. The cylinders and valve chests are cast in one piece, and all have slide valves, excepting the high-pressure cylinders of the 40 and 50-foot cutters, which have piston valves. The pistons are dished, of wrought steel, and have one packing ring each, sprung into a groove in their face. The piston rods of types B_3, G_2 and E_2 are screwed into the pistons and secured by locknuts, while in type Z they have taper ends fitted into the piston hubs, with nuts on the outside. The crosshead ends of the connecting rods in types B_3, G_2 and E_2 are adjustable by wedges and bolt; in type Z, by regular caps and bolts in the crosshead, the end having a spade-handle shape. The crank ends of the connecting rods of types B_3 and G_2 are fitted with straps, gibs and keys, while in types E_2 and Z, they are of the regular marine-engine type, with two bolts. The Stephenson link is used on all types, in the form of a box link; this form of link gives larger wearing surfaces than any other and has furthermore the advantage that in case of repairs it can be overhauled and taken apart quickly. The link blocks can easily be made by any machinist and of any scrap of sheet brass, $\frac{5}{8}$ inch thick, that may be on hand. The joints in the link gear are made as large as possible and all of

50 Ft. Cutter Engine, Type Z

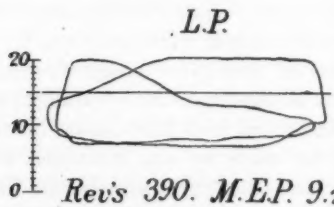
Cylinders 5¾", 9¼" & 15¼" x 9".



Rev's 390. M.E.P 102.3 lbs.
IHP. 45.97 Vacuum 14.24 lbs.



Rev's 390. M.E.P. 38.4 lbs.
IHP. 45.33 Vacuum 14.24 lbs.



Rev's 390. M.E.P. 9.23 lbs.
IHP. 29.78 Vacuum 14.24 lbs.

them are bushed with hardened steel bushes, which can easily be replaced. All small pins are hardened. The type Z engine for the 50-foot cutter engine is a triple-expansion engine with the low-pressure cylinder forward, the high-pressure cylinder in the middle and the intermediate cylinder aft. They are supported on wrought-steel columns, stiffened by horizontal and diagonal braces. The piston rods are hollow and the crank shaft is supported in five bearings cast on the bedplate. The air pump is worked by a beam from the low-pressure crosshead. All engines are fitted with ample arrangements for oiling all moving parts and have also ample facilities for draining the cylinders and valve chests. In the 50-foot steam cutter an 18-inch fan, direct connected to a single-cylinder engine of 2-inch by 2-inch, forces air into a duct leading into the ash pit.

The particulars of a trial of a 40-foot cutter for which the indicator diagrams are given are: Trial displacement, 18,850 pounds; draught, forward, 2 feet 2⅞ inches; draught, aft, 2 feet 11½ inches; steam pressure, 160 pounds; maximum I.H.P. 49.52; greatest speed, 8.76 knots. The steam jet was used, and the coal consumption per I.H.P. was 4.87 pounds. The slip of the screw was 38.2 per cent., and the temperature of the sea was 41 degrees, of the hotwell, 117 degrees, and of the feed tank, 102 degrees.

In a trial of a 50-foot cutter, for which also indicator diagrams are given, the following was attained with a steam pressure of 200 pounds: Maximum I.H.P., 121.08; greatest speed, 10.08 knots; slip of screw, 37.7 per cent. The temperature of sea was 46 degrees, and that of the hot well, 57 degrees.

Appended tables of dimensions of engines, boilers, etc., and their weights will be found useful.

Boat.						
Length over all, feet	28	30	33	36	40	50
Breadth, extreme	7′ 8″	8′ 0″	8′ 7″	8′ 9″	9′ 0″	10′ 0″
Depth from top of deck to rabbet of keel	4′ 3″	4′ 1½″	4′ 5″	4′ 8″	4′ 7½″	5′ 3″
Draught, mean	2′ 5″	2′ 5″	2′ 7″	2′ 5½″	2′ 7½″	2′ 9½″
Displacement, pounds	10430	11861	14436	16961	19680	31400
Number of men carried, maximum	35	40	48	53	60	75
Speed, knots per hour	6½	6½	7½	7½	9	10
Engine.						
Diameter of H.P. cylinder, inches	3½	3½	4	4	5	5½
I.P. cylinder, inches	...	...	...	...	...	9½
L.P. cylinder, inches	7	7	8	8	10½	15½
Stroke of pistons	6	6	6	6	8	9
Revolutions per minute	350	350	350	350	350	400
Horsepower	14.28	14.28	18.65	18.65	48.87	123.61
Diameter of crank shaft	2	2	2	2	2½	2½
crank pins	2	2	2	2	2½	2½
Length in ins. of 1st crank-shaft bearing, from f'w'd.	2	2	2½	2½	3	3 5/16
2d crank-shaft bearing, from f'w'd.	3	3	3½	3½	4	3 5/16
3d crank-shaft bearing, from f'w'd.	2	2	2½	2½	3	3 5/16
4th crank-shaft bearing, from f'w'd.	...	...	...	...	...	4 1/16
5th crank-shaft bearing, from f'w'd.	...	...	...	...	...	3 5/16
Diameter of crank-shaft bearing bolts	½	½	½	½	½	½
Length of crank pins	2	2	2½	2½	2½	3½
Thickness of H.P. crank web	½	½	½	½	1½	1½
L.P. crank web	½	½	1	1	1½	1½
Breadth of crank web	2½	2½	2½	2½	2½	3½
Throw of H.P. eccentrics	1½	1½	1½	1½	2½	2½
I.P. eccentrics	...	...	...	...	...	2½
L.P. eccentrics	1½	1½	1½	1½	2½	3
Diameter of H.P. eccentrics	3½	3½	4	4	5½	5½
I.P eccentrics	...	...	...	...	...	5½
L.P. eccentrics	3½	3½	4	4	5½	5½
Width of H.P. eccentric	1⅛	1⅛	1⅛	1⅛	1⅛	1
I.P. eccentric	...	...	...	...	...	1
L.P. eccentric	1⅛	1⅛	1⅛	1⅛	1⅛	1
Diameter of air-pump eccentric	3½	3½	3½	3½	5½	...
Width of air-pump eccentric	1⅛	1⅛	1⅛	1⅛	1	...
Throw of air-pump eccentric	1½	1½	1½	1½	2½	...
Diameter of thrust collars	3½	3½	3½	3½	4	4½
Width of thrust collars	½	½	½	½	½	½
Space between thrust collars	½	½	5/16	5/16	½	½
Number of thrust collars	2	2	3	3	4	5
Diameter of crank-shaft coupling disk	4	4	4½	4½	6	5½
Thickness of crank-shaft coupling disk	½	½	½	½	½	½
Number of coupling bolts	4	4	4	4	4	4
Diameter of coupling bolts	⅜	⅜	½	½	½	½
Pitch circle of coupling bolts	2½	2½	3½	3½	4½	4½
Diameter of piston rods	½	½	½	½	1⅛	1½
Diameter of hole in same	...	...	...	...	...	...
Length of piston rod from under side of piston to center crosshead	10½	10½	10½	10½	13½	17½
Smallest diameter of rod in piston hub	⅞	⅞	⅞	⅞	1	1
Width of pistons on face	½	½	½	½	1	1½
Thickness of H.P. piston near hub	5/16	5/16	¼	¼	¼	¼
I.P. piston near hub	...	...	...	...	...	5/16
L.P. piston near hub	⅜	⅜	½	½	½	½
H.P. piston near edge	5/16	5/16	¼	¼	5/16	¼
I.P. piston near edge	...	...	...	...	...	¼
L.P. piston near edge	¼	¼	¼	¼	5/16	¼
Diameter of piston hubs	1½	1½	1½	1½	2	2½
Width of piston rings	5/16	5/16	¼	¼	¼	¼
Thickness of H.P. piston ring	5/16	5/16	¼	¼	¼	¼
I.P. piston ring	...	...	...	...	...	¼
L.P. piston ring	5/16	5/16	¼	¼	¼	5/16
Diameter of crosshead-pin bearing	1½	1½	1½	1½	1½	1½
Length of crosshead-pin bearing	2	2	2½	2½	2½	2½
Width of crosshead	2	2	2½	2½	2½	3½
Length of crosshead	2½	2½	3½	3½	3½	5
Length of connecting rod, center to center	15	15	15	15	20	22½
Diameter of connecting rod, crosshead end	½	½	½	½	1	1½
connecting rod, crank end	1	1	1	1	1½	1½
connecting-rod bolts	...	...	...	...	½	½
Distance between C.R. bolts, center to center	...	...	...	...	3½	4

Thickness of crank-pin brasses						
H.P. cylinder barrel						
I.P. cylinder barrel	...	...	...	...	...	
L.P. cylinder barrel						
Length of cylinder barrel						
Thickness of cylinder bottom						
covers						
flanges						
Diameter of H.P. cylinder cover	6	6	6½	6½	8½	9
I.P. cylinder cover	...	...	...	...	...	
L.P. cylinder cover	9½	9½	10½	10½	13½	18½
Number of bolts in H.P. cylinder cover	4	4	4	4	6	8
I.P. cylinder cover	...	...	...	...	...	
L.P. cylinder cover	7	7	9	9	10	18
Pitch circle of bolts in H.P. cover	4½	4½	5½	5½	6½	7½
I.P. cover	...	...	...	...	...	11
L.P. cover	8½	8½	9½	9½	12	17
Diameter of bolts in cylinder covers						
Length of H.P. cylinder steam ports						
I.P. cylinder steam ports	...	...	...	...	...	1
L.P. cylinder steam ports						
Breadth of H.P. cylinder steam ports	2	2	2	2	2½ dia.	2½ dia.
I.P. cylinder steam ports	...	...	...	...	...	8½
L.P. cylinder steam ports	4½	4½	6	6	8	15
Length of bridges, H.P.						
I.P.	...	...	...	...	...	
L.P.						
exhaust port, H.P.						
I.P.	...	...	...	...	...	
L.P.						
Slide or piston valve and diameter of piston, H.P.	S.	S.	S.	S.	P. 1½	P. 2½
I.P.	...	...	...	...	...	S.
L.P.	S.	S.	S.	S.	S.	S.
Steam lap top of H.P. valve						
bottom of H.P. valve						
top of I.P. valve	...	...	...	...	...	
bottom of I.P. valve	...	...	...	...	...	
top of L.P. valve						
bottom of L.P. valve						
Exhaust lap top of H.P. valve						
bottom of H.P. valve	0	0	0	0		
top of I.P. valve	...	...	...	...	...	
bottom of I.P. valve	...	...	...	...	...	
top of L.P. valve					0	
bottom of L.P. valve						
Angular advance, H.P., degrees	40½	40½	41½	41½	36	39
I.P., degrees	...	...	...	...	...	38½
L.P., degrees	40½	40½	41½	41½	40	45
Steam lead, angular top H.P., degrees	8	8	10½	10½	6½	9
bottom H.P., degrees	13	13	12½	12½	9½	12½
top I.P., degrees	...	...	...	...	...	
bottom I.P , degrees	...	...	...	...	...	
top L.P., degrees	8	8	10½	10½	11½	8
bottom L.P., degrees	13	13	12½	12½	15	12½
Cut-off of H.P. cylinder, top	.69	.69	.696	.696	.75	.72
bottom	.642	.642	.625	.623	.691	.67
I.P. cylinder, top	...	...	...	...	...	.682
bottom	...	...	...	...	...	.635
L.P. cylinder, top	.69	.69	.696	.696	.727	.613
bottom	.642	.642	.625	.625	.672	.56
Release, H.P. cylinder, top	.136	.156	.15	.15	.094	.115
bottom	.142	.142	.145	.145	.086	.150
I.P. cylinder, top	...	...	...	...	...	.16
bottom	...	...	...	...	...	.18
L.P. cylinder, top	.056	.056	.05	.05	.094	.085
bottom	.0486	.0486	.05	.05	.102	.089
Compression, H.P. cylinder, top	.083	.083	.091	.091	.086	.1
bottom	.101	.101	.11	.11	.094	.075
I.P. cylinder, top	...	...	...	...	...	.058
bottom	...	...	...	...	...	.06
L.P. cylinder, top	.222	.222	.208	.208	.136	.225
bottom	.205	.205	.245	.245	.128	.2
Velocity of steam, H.P. cylinder port, top	75	75	93.7	93.7	101.8	87.2
bottom	63	63	86	86	93.16	78.4
I.P. cylinder port, top	...	...	...	...	...	168
bottom	...	...	...	...	...	140
L.P. cylinder port, top	133	133	125	125	134.4	178
bottom	114	114	115	115	122.4	153
exhaust, H.P. cylinder, top	45	45	58	58	69.8	65.4
bottom	45	45	58	58	69.8	65.4

Velocity of exhaust, I.P. cylinder, top	...	...	...	...	..	79
bottom	...	..	...	...	...	79
L.P. cylinder, top	100	100	78	78	96.6	105
bottom	89	89	86.7	86.7	96.6	105
Clearance on top of pistons						
bottom of pistons						
Diameter of H.P. valve stem						
I.P. valve stem	...	...	...	...	...	
L.P. valve stem						
Diameter of valve-stem pins						
Length of valve each side of stem						
link block	2¼	2¼	2¼	2¼	3½	3½
Width of groove in link	1⅛	1⅛	1⅛	1⅛	1⅛	1⅛
Radius of link	14 5/16	14 5/16	14 5/16	14 5/16	18⅜	23⅜
Distance from center to center knuckles	3 5/16	3 5/16	3 5/16	3 5/16	4⅜	6
center link to center knuckles	1⅛	1⅛	1⅛	1⅛	1⅛	1 1/16
center to center pillar bolts	7½	7½	7½	7½	8½	10½
Diameter of knuckle-joint bearings					1 1/16	
Length of knuckle-joint bearings	1½	1½	1½	1½	1½	1½
Diameter of saddle pin						
Length of saddle pin						
Offset of saddle pin above link					5/16	5/16
Diameter of eccentric rods near link						
eccentrics	⅛x2	⅛x2	⅛x2	⅛x2	3	
Length of eccentric rods from center	12⅛	12⅛	12⅛	12⅛	17⅛	21⅛
Diameter of eccentric bolts					1/16	
Length of suspension links, center to center	2½	2½	2½	2½	5 5/16	8½
Diameter of suspension links, center to center						7/16
Length of reversing arms	5	5	4⅜	4⅜	7	7½
Diameter of reversing shaft					1	1⅛
Length of reversing-shaft bearings	1⅛	1⅛	1⅛	1⅛	2	1⅛
Diameter of reversing-shaft bolts	7/16	7/16	7/16	7/16	7/16	7/16
Diameter of piston-rod stuffing boxes	1½	1½	1½	1½	1½	2½
valve-rod stuffing boxes	1½	1½	1½	1½	1½	1½
Depth of packing space, piston rod	1½	1½	1½	1½	1½	2½
valve rod	1	1	1	1	1½	1½
Diameter of frame bolts, top	⅝	⅝	9/16	9/16	⅝	⅝
bottom	⅝	⅝	9/16	9/16	⅝	⅝
holding-down bolts	⅝	⅝	9/16	9/16	⅝	⅝
Number of holding-down bolts	6	6	6	6	6	10
Diameter of columns	...	...	...	...	...	1 1/16
Number of columns	...	...	...	...	...	10
Diameter of horizontal braces	...	...	...	...	...	⅛
diagonal braces	...	...	...	...	...	⅛
strong-back braces	...	...	...	...	...	1
Diameter of air-pump cylinder	2	2	2	2	2	4½
Stroke of air pump cylinder	1½	1½	1½	1½	2½	3
Diameter of air-pump piston rod	⅝	⅝	⅝	⅝	7/16	½
Boiler.						
Type—Ward	B round	D round	D sq.	G_2 sq.	G_1 r'd.	H_1 sq., imp'd.
Heating surface, square feet	98	145	140	182	207	337
Grate surface, square feet	4.9	6.87	7	9	9 37	14
Ratio of H.S. to G.S.	20	21	20	20	22	24
Diameter or width of boiler casing	38½	42	41	44¼	50½	53½
Height to top of boiler casing	40½	46¼	40	44	51½	58
of ash pan	9	9	9	10	9	10
steam drum	63	70	60	68	80½	86
Diameter of steam drum	15	16	16	18	18	24
steam-drum casing	21½	20	22½	26½	26½	33½
smoke pipe, outside	13	15	15	17½	17½	21½
inside	11	13	13	15½	15½	19
Number of bent tubes 1½ ins. diameter	44	48	56	64	56	76
straight tubes 1½ ins. diameter	34	51	62	86	61	124
Diameter of safety valve	1	1	1½	1½	1½	2
Number of feed pumps	1	1	1	1	2	2
Diameter of steam cylinder	2	2	2	2	2	3½
water cylinder	1½	1½	1½	1½	1½	2½
Stroke of pistons	2½	2½	2½	2½	2½	4
Feed tank capacity, gallons	88	102	121	119	153	194
Coal bunker capacity, pounds	500	700	1000	1120	1600	3360
Condenser.						
Total cooling surface, square feet	6.91	7.12	8.97	9.3	19.56	58.55
Cooling surface per H.F.	.484	.498	.493	.498	.457	.488
Number of pipes	1	1	1	1	1	2
Diameter at exhaust end	1½	1½	2½	2½	3	3½
air-pump suction	½	½	½	½	1	1

Shafting.						
Diameter of line shaft	2½	2½	1⅝	1⅝	2	2⅛
Length of line shaft	4′ 7⅝″	4′ 10″	5′ 11¼″	6′ 10″	5′ 8″	5′ 9⅛″
Diameter of forward coupling	4	4	4⅜	4⅜	6	5⅜
Thickness of forward coupling	⅝	⅝	⅝	⅝	⅝	⅝
Diameter of after coupling	4	4	4⅜	4⅜	5⅜	3⅜ al'ves.
Thickness of after coupling	⅝	⅝	⅝	⅝	⅝	8¼ long.
Number of bolts, after coupling	3	3	3	3	4	...
Diameter of bolts, after coupling	⅝	⅝	⅝	⅝	⅝	...
Pitch circle, after coupling	2⅜	2⅜	3⅛	3⅛	4	...
Length of propeller shaft	4′ 9⅛″	5′ 4⅛″	6′ 1⅛″	6′ 3⅛″	6′ 7⅛″	7′ 10⅛″
Diameter of propeller shaft	1½	1½	1⅝	1⅝	2	2⅛
Length of stern-tube bearing, forward	3	3	3½	3½	4½	6
aft	4⅛	4⅛	5⅛	5½	7⅛	8⅛
Diameter of stern-tube bearings	1⅝	1⅝	1⅝	1⅝	2⅛	3
Length of taper, propeller shaft	3⅛	3⅛	4	4	5	5⅛
Diameter at end of taper	⅛	⅛	1½	1½	1⅝	2⅛
of screw end	½	½	1	1	1⅛	1⅛
Length of screw end	1	1	1½	1½	1⅝	1⅞
Propeller.						
Diameter	26	27	30	31	32	36
Pitch, true	42	48	48	42	54	50½
Number of blades	4	4	4	4	4	4
Thickness of blades at hub	⅞	⅞	⅞	⅞	1	1⅛
tip	⅛	⅛	⅛	⅛	⅛	⅛
Helicoidal area, square inches	320	319	350	391	470	602
Projected	241	223	301	303	336	466
Piping.						
Steam to engine, diameter and B.W.G., if of copper; iron pipe size,—I.P.S., if of brass	1½ 13	1½ 13	1½ 13	1½ 13	1½ 13	1½ 12
Bleeder	½ 12	½ 12	½ 12	½ 12	½ 12	1¼ 13
Steam to feed pump	½ 15	½ 15	½ 15	½ 15	½ 15	½ 15
blower	... ...	... ...	... ...	... ...	... ...	½ 15
Exhaust from engine	1½ 15	1½ 15	2½ 15	2½ 15	3 15	4½ 14
feed pump	½ 15	½ 15	½ 15	½ 15	¾¼½ 15	2¼½ 15
blower	... ...	... ...	... ...	... ...	... ...	½ 15
Air-pump suction	½ 15	½ 15	½ 15	½ 15	1 15	1¼ IPS
discharge	½ 15	½ 15	½ 15	½ 15	1 15	1¼ IPS
Escape from safety valve	1 15	1 15	1½ 15	1½ 15	1½ 15	2 15
Steam to water gauge	½ IPS	½ IPS	½ IPS	½ IPS	½ IPS	½ IPS
steam gauge	½ IPS	½ IPS	½ IPS	½ IPS	½ IPS	½ IPS
whistle and jet	½ IPS	½ IPS	½ IPS	½ IPS	½ IPS	... ...
jet	½ IPS	½ IPS	½ IPS	½ IPS	½ IPS	½ IPS
whistle	½ IPS	½ IPS	½ IPS	½ IPS	½ IPS	½ IPS
Feed-pump suction	½ IPS	½ IPS	½ IPS	½ IPS	½ IPS	1¼ IPS
discharge to boiler	½ IPS	½ IPS	½ IPS	½ IPS	½ IPS	1¼ IPS
Tank connection	½ IPS	½ IPS	½ IPS	½ IPS	½ IPS	1¼ IPS
Water-gauge connection	½ IPS	½ IPS	½ IPS	½ IPS	½ IPS	1¼ IPS
Blow-off overboard	½ IPS	½ IPS	½ IPS	½ IPS	½ IPS	1¼ IPS
Bilge-pump suction	½ IPS	½ IPS	½ IPS	½ IPS	1¼ IPS	1¼ IPS
discharge	½ IPS	½ IPS	½ IPS	½ IPS	½ IPS	1¼ IPS
Vent from tank under boiler	½ IPS	½ IPS	½ IPS	½ IPS	½ IPS	½ IPS
Air-compressor connection	... ...	... ...	... ...	... ...	1¼ ...	... ...
Air-pump connection with tanks	... ...	... ...	... ...	... ...	½ IPS	... ...
Receiver pipe from H.P. cylinder	1½ 13	1½ 13	1½ 13	1½ 13	1½ 12	2½ 12
I.P. cylinder	... ...	... ...	... ...	... ...	... ...	3½ 13
Weights.						
Hull, exclusive of fittings, pounds	4007	4390	5510	7037	8064	13591
inclusive of fittings	4735	5205	6492	8084	9125	14991
Machinery, empty	2700	3550	3875	4750	5690	10015
Water in boiler	150	156	168	225	300	525
tanks	733	850	1010	991	1270	1600
condenser	15	15	17	17	20	24
filter	10	22	22	22	22	22
Coal	500	700	1000	1120	1600	4100
Coal bunkers	225	340	360	400	459	*
Machinery, ready for service	4333	5033	6452	7325	9361	16345
Air pump	11	11	11	11	12	†
Condenser	79	98	119	109	127	352
Feed pumps	80	86	83	69	158	325
Shafting	71	69	142	114	174	347
Propeller	40	38	65	70	90	125
Piping	151	200	194	222	384	300
Water tanks	206	205	233	230	328	...
Flooring	172	202	181	171	175	285
Spare parts	24	25	25	25	25	30

* In machinery. † In engine.

BRITISH TRIALS OF TORPEDO BOAT DESTROYERS.

RETURN "GIVING THE NAMES OF ALL THE VARIOUS TORPEDO-BOAT DESTROYERS WHICH HAVE BEEN BUILT FOR THE BRITISH ADMIRALTY, STATING THE DATE WHEN THEY WERE ORDERED AND OF WHOM, THE DATES WHEN THEY WERE LAUNCHED, THE NUMBER OF OFFICIAL TRIALS TO WHICH THEY WERE SUBJECTED, AND THE DATES WHEN THEY WERE ACCEPTED BY THE ADMIRALTY, OR, IN THE CASE OF UNFINISHED BOATS, THE EXPECTED DATE OF DELIVERY; ALSO THE NUMBERS OF PRELIMINARY TRIALS OF BOATS OF 30 KNOTS OR OVER, AND PARTICULARS OF TYPICAL CASES WHERE THOSE TRIALS HAVE BEEN EXCEPTIONAL IN NUMBER AND HAVE EXTENDED OVER CONSIDERABLE PERIODS."

Names.	Where built.	Date when ordered.	Date of launching.	Number of official trials.	Date when accepted.	Expected date of delivery.	Number of preliminary trials of boats of 30 knots or over	Particulars of typical cases where those trials have been exceptional in number, and have extended over considerable periods.	Remarks.
Havock.....	Yarrow & Co., Poplar,	27 June 1892	12 Aug. 1893	1	15 Jan. 1894	...	...	.....	Original locomotive boilers have been replaced by water-tube type.
Hornet.....	"	"	23 Dec. 1893	1	10 June 1894	...	...	.....	Copper boiler tubes replaced by steel.
Daring.....	Thornycroft, Chiswick,	"	25 Nov. 1893	1	17 Oct. 1894	...	...	.....	.....
Ferret.....	Laird Bros., Birkenhead	6 Jan. 1893	9 Dec. 1893	1	17 Sep. 1894	...	...	.....	.....
Decoy.....	Thornycroft, Chiswick,	27 June 1892	2 Feb. 1894	1	17 Oct. 1894	...	...	.....	.....
Lynx.....	Laird Bros., Birkenhead	6 Jan. 1893	24 Jan. 1894	1	7 Dec. 1894	...	...	.....	.....
Hasty.....	Yarrow & Co., Poplar,	12 Oct. 1893	16 June 1894	3	11 Jan. 1896	...	...	.....	Original locomotive boilers have been replaced by water-tube type.
Charger.....	"	"	15 Sep. 1894	2	25 July 1895	...	...	.....	
Dasher.....	"	"	28 Nov. 1894	2	30 June 1895	...	...	.....	
Ardent.....	Thornycroft, Chiswick,	13 Oct. 1893	16 Oct. 1894	2	29 Mar. 1895	...	...	.....	.....
Boxer.....	"	"	28 Nov. 1894	1	30 June 1895	...	...	.....	.....
Conflict.....	J. S. White & Co., Cowes	3 Nov. 1893	13 Dec. 1894	2	2 Mar. 1899	...	...	Trials began Aug. 16, 1895, and lasted till June 9, 1898. Delay principally due to alterations to obtain speed.	.....
Rocket.....	Thomson's, Glasgow,	"	14 Aug. 1894	2	27 Aug. 1895	...	...	.....	Copper tubes in boilers replaced by steel.
Shark.....	"	"	22 Sep. 1894	2	"	...	...	.....	
Surly.....	"	"	10 Nov. 1894	1	"	...	...	.....	
Sturgeon.....	Naval Construction and Armaments Company, Barrow,	8 Dec. 1893	21 July 1894	7	17 Feb. 1896	...	...	.....	
Banshee.....	Laird Bros., Birkenhead	7 Feb. 1894	17 Nov. 1894	1	11 May 1895	...	...	.....	.....
Contest.....	"	"	1 Dec. 1894	1	"	...	...	.....	.....
Dragon.....	"	"	15 Dec. 1894	1	5 July 1895	...	...	.....	.....
Bruizer.....	Thornycroft, Chiswick,	13 Oct. 1893	27 Feb. 1895	1	24 July 1895	...	...	.....	.....
Teazer.....	J. S. White & Co., Cowes	3 Nov. 1893	9 Feb. 1895	4	12 Sep. 1898	...	...	Trials began Jan. 3, 1896, and lasted till March 22, 1898. Delay due principally to alterations to obtain speed and breaking of shaft bracket.	.....
Wizard.....	J. S. White, Cowes,	"	26 Feb. 1895	2	6 Jan. 1899	...	...	Trials began May 19, 1897, and lasted till May 5, 1898. Delay due principally to alterations to obtain speed.	.....
Janus.....	Palmer's Company, Jarrow,	"	12 Mar. 1895	2	2 Dec. 1895	...	...	.....	.....
Lightning....	"	"	10 Apr. 1895	1	21 Jan. 1896	...	...	.....	
Fervent.....	Hanna, Donald & Wilson, Paisley,	3 Nov. 1893	28 Mar. 1895	6 with new boilers.	14 May 1900	...	...	Trials began Aug. 23, 1895, and continued till Feb'y, 1896. Locomotive boilers then removed and water-tube boilers fitted. Trials then lasted from June 12, 1899, till Aug. 4, 1899.	Finally accepted at 26¼ knots.

James	Palmer's Company, Jarrow,	"	12 Mar. 1895	2	2 Dec. 1895	...	...	.....	.....
Lightning	"	"	10 Apr. 1895	1	21 Jan. 1896	...	...	.....	
Fervent	Hanna, Donald & Wilson, Paisley,	3 Nov. 1893	28 Mar. 1895	6 with new boilers.	14 May 1900	...	...	Trials began Aug. 23, 1895, and continued till Feb'y, 1896. Locomotive boilers then removed and water-tube boilers fitted. Trials then lasted from June 12, 1899, till Aug. 4, 1899.	Finally accepted at 26¼ knots.
Zephyr	"	"	10 May 1895	3 with new boilers.	30 Jan. 1901	...	...	Trials began March 13, 1896. Locomotive boilers then removed and water-tube boilers fitted. Trials then lasted from J'ly 5, 1900, till Sep. 8, 1900	.....
Starfish	Naval Construction and Armaments Company, Barrow,	8 Dec. 1893	26 Jan. 1895	1	25 Feb. 1896	...	...	.....	Copper tubes in boilers replaced by steel.
Skate	"	"	13 Mar. 1895	1	"	...	...	.....	
Swordfish	Armstrong & Co., Newcastle-on-Tyne.	"	27 Feb. 1895	4	2 Dec. 1896	...	...	.....	.....
Salmon	Earle's Company, Hull.	"	15 Jan. 1895	3	30 Jan. 1896	...	...	.....	.....
Snapper	"	"	30 Jan. 1895	2	"	...	...	.....	.....
Sunfish	Hawthorn's, Newcastle-on-Tyne.	7 Feb. 1894	23 May 1895	2	14 Feb. 1896	...	...	.....	.....
Spitfire	Armstrong & Co., Newcastle-on-Tyne.	"	7 June 1895	1	3 Nov. 1896	...	...	.....	.....
Handy	Fairfield Company, Glasgow.	"	9 Mar. 1895	2	11 Oct. 1895	...	...	.....	.....
Hart	"	"	27 Mar 1895	1	15 Jan. 1896	...	...	.....	.....
Porcupine	Palmer's Company, Jarrow.	3 Nov. 1893	19 Sep. 1895	2	28 Mar. 1896	...	...	.....	.....
Haughty	Doxford & Sons, Sunderland.	"	18 Sep. 1895	2	9 June 1896	...	...	.....	Copper tubes in boilers replaced by steel before trials.
Hardy	"	"	16 Dec. 1895	2	29 Aug. 1896	...	...	.....	
Opossum	Hawthorn's, Newcastle-on-Tyne.	7 Feb. 1894	9 Aug. 1895	1	14 Mar. 1896	...	...	.....	.....
Ranger	"	"	4 Oct. 1895.	1	2 June 1896	...	...	.....	.....
Hunter	Fairfield Company, Glasgow,	7 Feb. 1894	28 Dec. 1895	2	5 May 1896	...	...	.....	A Babcock & Wilcox boiler for this ship did not prove satisfactory, and another type was substituted.
Zebra	Thames Company, Blackwall,	"	3 Dec. 1895	1	21 Nov. 1899	...	...	Trials lasted from Dec. 16, 1895, to March 5, 1897. Delay in delivery due to renewal of boiler tubes.	.....
Quail	Laird Bros., Birkenhead	25 Apr. 1895	24 Sep. 1895	4	9 June 1897	...	12	Trials lasted from March 25, 1896, till January 4, 1897. Principally due to alterations in propellers to obtain speed.	.....
Sparrowhawk	"	"	8 Oct. 1895	2	25 Mar. 1897	...	9	.....	.....
Thrasher	"	"	5 Nov. 1895	6	10 June 1897	...	2	.....	.....
Virago	"	9 May 1895	19 Nov. 1895	3	1 Apr. 1897	...	4	.....	.....
Otter	Vickers, Sons & Maxim, Barrow,	20 Apr. 1896	23 Nov. 1896	8	10 Mar. 1900	...	22	The trials lasted from April 7, 1897, till July 18, 1899. This was due principally to (1) alterations in propellers to obtain speed; (2) fracture in both port and starboard crank shafts.	.....
Desperate	Thornycroft, Chiswick,	25 Apr. 1895	15 Feb. 1896	3	12 Feb. 1897	...	9	Trials lasted from March 4, 1896, till Sep. 24, 1896. The large number of preliminary trials was due to trying various propellers and to break-down of starboard M.P. engine.	.....
Fame	"	"	15 Apr. 1896	6	18 Aug. 1897	...	5	.....	.....
Foam	"	"	8 Oct. 1896	4	2 Sep. 1897	...	3	.....	.....
Mallard	"	29 May 1895	19 Nov. 1896	3	5 Nov. 1897	...	2	.....	.....
Brazen	Clydebank Company, Glasgow,	30 July 1895	3 July 1896	6	24 July 1900	...	21	Trials lasted from Sep. 17, 1896, till March 29, 1900. This was principally due to (1) alterations in propellers; (2) inability to obtain speed.	Vessel was finally accepted at 29¼ knots.
Electra	"	"	14 July 1896	3	18 May 1900	...	8	Delay in completing trials, principally due to difficulties experienced in obtaining speed.	Vessel was finally accepted at 29¼ knots.

Names.	Where built.	Date when ordered.	Date of launching.	Number of official trials.	Date when accepted.	Expected date of delivery.	Number of preliminary trials of boats of 30 knots or over	Particulars of typical cases where those trials have been exceptional in number, and have extended over considerable periods.	Remarks.
Recruit	Clydebank Company, Glasgow,	30 July 1895	22 Aug. 1896	4	30 July 1900	...	2	Delay in completing trials, principally due to difficulties experienced in obtaining speed.	Vessel was finally accepted at 29¼ knots.
Earnest	Laird Bros., Birkenhead	23 Dec. 1895	7 Nov. 1896	2	18 Nov. 1897	...	3	.....	.....
Griffon	"	"	21 Nov. 1896	3	"	...	2	.....	.....
Locust	"	9 Jan. 1896	5 Dec. 1896	6	2 July 1898	...	4	.....	.....
Star	Palmer's Company, Jarrow,	23 Dec. 1895	11 Aug. 1896	4	17 May 1898	...	7	.....	.....
Whiting	"	"	26 Aug. 1896	2	24 June 1897	...	4	.....	.....
Bat	"	9 Jan. 1896	7 Oct. 1896	3	21 Aug. 1897	...	3	.....	.....
Chamois	"	"	3 Nov. 1896	4	25 Nov. 1897	...	3	.....	.....
Crane	"	"	17 Dec. 1896	3	17 May 1898	...	3	.....	.....
Avon	Vickers & Company, Barrow,	23 Dec. 1895	10 Oct. 1896	5	30 Jan. 1899	...	16	Trials lasted from Jan. 23, 1897, to Oct. 19, 1898. Due principally to (1) alterations in propellers to obtain speed; (2) fracture of shaft bracket; (3) bending of crank shaft.	.....
Bittern	"	"	1 Feb. 1897	3	21 Mar. 1899	...	7	.....	.....
Angler	Thornycroft, Chiswick,	"	2 Feb. 1897	3	8 July 1898	...	3	.....	.....
Ariel	"	"	5 Mar. 1897	3	4 Oct. 1898	...	2	.....	.....
Fawn	Palmer's Company, Jarrow,	20 Apr. 1896	13 Apr. 1897	2	30 Nov. 1898	...	3	.....	.....
Flirt	"	"	15 May 1897	3	23 Mar. 1899	...	3	.....	.....
Flying Fish	"	9 Jan. 1896	4 Mar. 1897	3	17 May 1898	...	4	.....	.....
Violet	Doxford's, Sunderland,	20 Apr. 1896	3 May 1897	7	"	...	9	Trials lasted from May 13, 1897, till March 10, 1898. Due principally to (1) unsatisfactory working of automatic feed gear; (2) inability to obtain speed.	.....
Cygnet	Thornycroft, Chiswick,	"	8 Jan. 1898	2	10 July 1899	...	2	.....	.....
Bullfinch	Earle's Company, Hull,	"	10 Feb. 1898	6	Not yet accepted.	...	10	Trials lasted from Dec. 19, 1898, to Nov. 29, 1900. Due principally to (1) alterations to obtain speed; (2) break-down of starboard H.P. engine.	Vessel was finally accepted at 29 knots.
Dove	"	"	21 Mar. 1898	6	"	...	7	Trials lasted from May 5, 1899, to Sep. 20, 1900. Due principally to alterations made consequent on break-down of *Bullfinch*.	Vessel was finally accepted at 29 knots.
Mermaid	Hawthorn's, Newcastle-on-Tyne.	"	22 Feb. 1898	2	28 Aug. 1899	...	3	.....	.....
Leven	Fairfield Company, Glasgow,	6 Sep. 1897	28 June 1898	2	5 July 1899	...	5	.....	.....
Leopard	Vickers & Company, Barrow,	20 Apr. 1896	20 Mar. 1897	3	6 June 1899	...	7	.....	.....
Gipsy	Fairfield Company, Glasgow,	20 Apr. 1896	9 Mar. 1897	6	15 July 1898	...	10	Trials lasted from April 14, 1897, till Feb. 4, 1898. Due principally to (1) alterations to propellers to obtain speed; (2) breaking of cylinders and valve gear.	.....
Fairy	"	"	29 May 1897	3	17 Sept. 1898	...	5	.....	.....
Osprey	"	"	17 Apr. 1897	3	15 Sept. 1898	...	6	.....	.....
Sylvia	Doxford & Sons, Sunderland,	"	3 July 1897	3	1 Dec. 1898	...	5	.....	.....
Express	Laird Bros., Birkenhead,	18 July 1896	11 Dec. 1897	...	Not yet accepted.	Not fixed.	...	This vessel started preliminary trials on Oct. 20, 1898, and has since made 27 preliminary and 10 official trials, but satisfactory official trials have not yet been made. Due principally to inabil-	Vessel tendered for 33 knots.
Wolf	"	"	6 Mar. 1897	2	20 May 1898	...	3	.....	.....
Osprey	Thornycroft, Chiswick,	20 Apr. 1896	2 June 1897	7	16 July 1898	...	4	.....	.....
Cheerful	Hawthorn's, Newcas-	"	25 Nov. 1897	4	19 Oct. 1899	...	2	.....	.....
			14 July 1897	2	4 Jan. 1900		8	Trials lasted from	.....

Osprey.....	"	"	17 Sept. 1897	8	1 Dec. 1898	...	5	.....	.....
Sylvia.....	Doxford & Sons, Sunderland,	"	3 July 1897	8	"	...	5	.....	.....
Express.....	Laird Bros., Birkenhead,	18 July 1896	11 Dec. 1897	...	Not yet accepted.	Not fixed	...	This vessel started preliminary trials on Oct. 20, 1898, and has since made 27 preliminary and 10 official trials, but satisfactory official trials have not yet been made. Due principally to inabil-	Vessel tendered for 33 knots.
Fame.....	"	"	6 Mar. 1897	2	20 May 1898	...	4	.....	.....
Wolf.....	"	"	2 June 1897	7	16 July 1898	...	4	.....	.....
Coquette.....	Thornycroft, Chiswick,	20 Apr. 1896	25 Nov. 1897	4	19 Oct. 1899	...	2	.....	.....
Cheerful.....	Hawthorn's, Newcastle-on-Tyne,	"	14 July 1897	2	4 Jan. 1900	...	8	Trials lasted from March 30, 1898, to Sept. 28, 1899. Principally due to fitting new crank shaft to replace bent one.	.....
Vulture.....	Clydebank Company, Glasgow,	30 July 1895	22 Mar. 1898	2	22 Dec. 1899	...	20	Trials lasted from April 12, 1898, till March 10, 1899. Due principally to alterations in propellers to obtain speed.	.....
Kestrel.....	"	20 Apr. 1896	25 Mar. 1898	2	10 Feb. 1900	...	11	.....	.....
Albatross.....	Thornycroft, Chiswick,	"	19 July 1898	4	28 June 1900	...	17	Trials lasted from Oct. 13, 1898, till April 5, 1900. Chiefly due to alterations to propellers, &c., in order to obtain speed.	Vessel tendered for 32 knots, finally accepted at 31¼ knots.
Cynthia.....	"	"	3 Sept. 1898	3	4 Jan. 1900	...	1	.....	.....
Orwell.....	Laird, Birkenhead,	5 July 1897	29 Sept. 1898	3	18 Dec 1899	...	3	.....	.....
Lee.....	Doxford & Sons, Sunderland,	6 Sept. 1897	27 Jan. 1899	2	8 Mar. 1901	...	10	Trials lasted from Feb. 16, 1899, till Nov. 30, 1900. Due principally to break-down of port M.P. engine.	.....
Spiteful.....	Palmer's Company, Jarrow,	"	11 Jan. 1899	3	8 Jan. 1900	...	5	.....	.....
Petrel†.....	"	30 Mar. 1898	30 Mar. 1899	2	24 July 1900	...	3	.....	.....
Stag.....	Thornycroft, Chiswick,	7 Sept. 1897	18 Nov. 1899	4	10 Aug. 1900	...	2	.....	.....
Viper.....	Hawthorn's, Newcastle-on-Tyne,*	4 Mar. 1898	6 Sept. 1899	2	22 Mar. 1901	...	4	.....	.....
Falcon.....	Fairfield Company, Glasgow,	31 Mar. 1899	29 Dec. 1899	2	Not yet accepted.	...	3	.....	.....
Ostrich.....	"	"	22 Mar. 1900	2	"	...	2	.....	.....
Vixen.....	Vickers & Co., Barrow,	30 Mar. 1899	29 Mar. 1900	6	"	...	8	.....	Official trials complete. Vessel will be accepted at 29½ knots.
Myrmidon..	Palmer's Company, Jarrow,	"	26 May 1900	2	21 Mar. 1901	...	5	.....	.....
Arab.....	J. Brown & Co. (late Clydebank Company) Glasgow,	20 Oct. 1899	9 Feb. 1901	...	Not yet accepted.	Not fixed.	...	.....	Vessel tendered for 32 knots.
Greyhound..	Hawthorn's, Newcastle-on-Tyne,	30 Mar. 1899	6 Oct. 1900	2	"	...	7	.....	.....
Racehorse....	"	"	8 Nov. 1900	...	"	...	...	.....	.....
Roebuck.....	"	"	4 Jan. 1901	...	"	...	...	.....	.....
Syren.....	Palmer's Company, Jarrow,	"	20 Dec. 1900	2	"	...	3	.....	.....
Lively.....	Laird Bros., Birkenhead,	"	14 July 1900	2	"	Not fixed.	10	.....	.....
Sprightly....	"	"	25 Sept. 1900	...	"	"	...	.....	.....
Success.....	Doxford & Sons, Sunderland,	"	21 Mar. 1901	...	"	"	...	.....	.....
Cobra†.....	Armstrong & Co., Newcastle-on-Tyne,	8 May 1900	1900	2	"	...	...	.....	.....
Kangaroo†...	Palmer's Company, Jarrow,	"	8 Sept. 1900	2	"	...	3	.....	.....
Thorn†.....	J. Brown & Co., Clydebank,	31 Mar. 1900	17 Mar. 1900	6	26 Mar. 1901	...	11	Trials lasted from April 7, 1900, till Sept. 7, 1900. Due to (1) alterations of propeller to obtain speed; (2) breaking of eccentric rod and studs.	.....
Tiger†.....	"	"	19 May 1900	2	9 Mar. 1901	...	5	.....	.....
Vigilant†....	"	"	16 Aug. 1900	2	26 Mar. 1901	...	1	.....	.....

* Parsons Steam Turbine Company, Limited. † Purchased whilst building.

The "Naval and Military Record," commenting on the foregoing report, takes a rather optimistic view, as follows:

"The Parliamentary paper issued a few days since on the trials of torpedo-boat destroyers is calculated to convey a somewhat erroneous idea to the lay mind. The paper throws perhaps undue emphasis on the fact that the great majority of the 30-knot destroyers were unable to attain the speed for which they were designed, and some of them had to be accepted as boats of less speed than 30 knots. The fact is likely to be overlooked that the Admiralty, in giving out contracts for boats of this class, make certain stipulations and then leave the designs entirely to the judgment of the contractors. If, then, the boat fails to attain her speed, it is not through any miscalculation or error of judgment on the part of Admiralty officials, but to the inexperience of the contractors who design and build the boats. There is nothing startling in the disclosure that a 30-knot boat never reaches that speed after she is in commission, and the causes are so well known that it is hardly necessary to point out that when on trial a destroyer is at least 100 tons lighter than when she goes to sea under the pennant. On the whole the return is interesting, though it need not be alarming.

"In regard to speed tests a few examples may be quoted. The *Albatross* was ordered in 1896, and the trials, numbering seventeen, were spread over a period of six months, chiefly in consequence of alterations to propellers, &c., in order to gain speed. The vessel tendered for thirty-two knots and was finally accepted at thirty-one and a half knots. The *Express*, which has not yet been taken over, has been submitted to no fewer than twenty-seven preliminary and ten official trials, but satisfaction has not been obtained. The stipulated speed is thirty-three knots, but the boat has not been able to accomplish so much. In most cases the extended trials were rendered necessary by the failure to obtain the necessary speed. The *Bullfinch* was accepted at 29 knots and the *Dove* at 29¼ knots, as were also the *Brazen* and *Recruit*, while the *Electra* succeeded these, with 29½ knots. The *Fervent* was tested for six months, after which locomotive boilers gave place to water-tube, of which a two months' trial was made,

but the boat was finally accepted at 26¾ knots. All the new orders since 1900 have required thirty-two knots, but only four of these have been accepted."

"Engineering" gives the following analysis of the same report:

"A very instructive return has just been issued as a Parliamentary paper at the instance of Sir Edward Reed. It gives the names of all the various torpedo-boat destroyers which have been built for the British Admiralty, and states the dates when they were launched, the number of trials made, and the dates when they were accepted. For the earlier 27-knot boats only the number of official trials is given; but for the later 30-knot boats the preliminary trials are also enumerated. There are 113 of these little vessels in all. They have all been built by contract, the orders having been distributed between 15 firms, the numbers to each ranging between 19 to Laird's and one to the Thames Iron Works. Next to Laird's in point of numbers come Thornycroft's and Palmer's, each of which have constructed 12 boats. The Clydebank yard has turned out 12. Hawthorn's and Fairfield, 9 each; the Barrow yard, 8; Doxford's 6; Yarrow's 5; Earl's 4; Armstrong's and White's, of Cowes, 3 each; Hanna, Donald, and Wilson, 2; and, as stated, the Thames Iron Works, 1.

"Doubtless for a good many of the firms named the tale is told, for it is by no means a simple thing to get 30 knots from a vessel of about 400 tons displacement, even when the drawings are completed, and the boat has passed the ordeal of Admiralty inspection during construction.

"The return bears evidence to this. Some of the trials have been of a most protracted nature. Sometimes, in the latter boats, this may have been due to labor troubles, but we think the big strike did not greatly influence the result. In the column of the return marked "Particulars of typical cases where those trials have been exceptional in number and have extended over considerable periods" there is some instructive reading. As our readers are aware, the boats that had originally locomotive boilers have all been refitted with water-tube boilers, although the *Havock*, by Messrs. Yarrow and Co., the pioneer of the class, had locomotive boilers, and successfully passed her trial with

them. It will doubtless come as a surprise to the majority of our readers to find the Poplar firm so low down on the list as regards number of destroyers supplied to the British Navy. Considering the important part taken by Messrs. Yarrow in the construction of torpedo craft from the earliest days, and the great success of their craft built either for our own Navy or for foreign governments, it appears a matter for regret that more vessels of this class have not been supplied by them for the British Navy.

"The first vessels of this class built appear to have passed through the ordeal of official trial without difficulty. It will be remembered that four vessels were ordered as a commencement in 1892—two from Thornycroft and two from Yarrow. These got through and were accepted at the first trial, as also were two boats ordered later on from Laird's. It is only when we come to the twelfth vessel on the list—the *Conflict*, built at Cowes—that we meet with record of serious trouble. This vessel began her trials in August, 1895, but did not get through until June, 1898. The *Teazer* had almost as bad a time, for she was two years and two months in getting passed. Her builders must have thought her the most appropriately named vessel ever built before they got rid of her. The *Fervent* and *Zephyr*, built on the Clyde, and having originally locomotive boilers, were still more unfortunate, for the former was four years before she could reach 26¾ knots, being accepted at that; and the latter was four years and five months making trials at intervals. The *Zebra*, built at Blackwall, was more moderate in her demands on her builders, her trials lasting only a year and a quarter.

"We now come to the 30-knot vessels, concerning which the number of preliminary trials is enumerated. We will only notice those whose preliminary trials ran into double figures. The first is the *Quail*, built at Birkenhead. She had twelve preliminary and four official trials between March 25, 1896, and January 4, 1897. The *Otter*, built at Barrow, had twenty-two preliminaries and eight officials between April 7, 1897, and July 18, 1899. This unusual number was principally due to trouble with propellers, but she also fractured both her port and her starboard crankshafts, which naturally delayed her somewhat. Another troublesome

destroyer to her builders was the *Brazen*, built at Clydebank. Her trials lasted from September 17, 1896, till March 29, 1900, during which time she made twenty-one preliminaries and six officials, being finally taken over at 29¼ knots. One other vessel from the same yard was also accepted at the same reduced speed, whilst another was half a knot short of the 30 knots. Both these vessels, however, made fewer trials. The next difficult vessel on the list was the *Avon*, built at Barrow. She made sixteen preliminary and five official trials, in the course of which she fractured a shaft bracket and bent a crankshaft. The *Bullfinch*, which had so tragic an experience, also made ten preliminary trials and six official trials, and only succeeded in getting 29 knots. The *Dove*, a sister ship, was passed at 29 knots. The *Gipsy*, built on the Clyde, had ten preliminary and six official trials.

"The next notable trials were those of the *Express*, and this vessel, together with the *Albatross*, stands on a somewhat different platform to the rest. The *Express* was contracted for by Laird's, of Birkenhead, at the remarkable speed of 33 knots. Her builders were apparently somewhat sanguine; at any rate their courage has not met with the reward one always likes to see accompany that quality. The boat started her preliminary trials on October 20, 1898, and has since then made twenty-seven preliminary and ten official trials, but has not yet been passed. Every good engineer will hope she may soon get through.

"The *Albatross*, as everyone knows, was built at Chiswick. Her contract was for 32 knots, which, though not so bold a flight as that of the *Express*, was two knots in advance of the other craft of the time. She made seventeen preliminary and four official trials, the trouble experienced in getting her through being chiefly due to the propellers. She was finally accepted at half a knot short of the contract speed. Her record being, however, 31½ knots, places her at the head of all craft afloat, excepting the *Turbinia*.

"The failure of this vessel to come up to her designer's expectations is instructive. Remembering the study Mr. Thornycroft and Mr. Barnaby have given to the propeller question, and their undoubted authority on the subject, it would seem that we have, with the 30 or 31-knot destroyer, arrived at a parting of the ways

in regard to propellers, and that new elements must enter into our calculations. Those who have followed the work of the two gentlemen named, especially that referring to cavitation, in their paper at the Institution of Civil Engineers, or in Mr. Barnaby's book, "Marine Propellers," will recognize the suggestiveness of the statements in the official return pointing out how frequently the difficulty in reaching speed was due to the propellers.

"The *Vulture*, built at Clydebank, made twenty preliminary and two official trials; the *Kestrel*, from the same yard, made eleven official and two preliminary trials. The *Lee*, built at Sunderland, made ten preliminary and two official trials; the *Lively*, built at Birkenhead, made ten preliminary and two official trials, but has not yet been delivered; and, finally, the *Thorn*, built at Clydebank, has made eleven preliminary and six official trials.

"We notice that some of the vessels in the list are referred to as having been "purchased whilst building." The practice is not to be commended, although doubtless, as in the case of war threatening, the Government is wise to secure all the vessels it can. It is, however, somewhat unfair to builders who have to undergo all the rigors of Admiralty inspection, and have to comply with all the expensive requirements of the British Navy, that they should be put in competition with those who have a free hand, or are only subject to the less exacting yoke of the foreign governments.

"It would be vastly instructive if the records of destroyers built for foreign navies could be obtained, and placed alongside those on the Parliamentary paper. With a view to making such comparison, we have asked Messrs. Thornycroft & Co. and Messrs. Yarrow & Co. to furnish us with corresponding particulars of trials of the Japanese destroyers which they have lately built. The particulars we give in Tables I and II, the former containing particulars of the boats built by the Chiswick firm, and Table II those of the Yarrow boats. We also draw attention to the trial of the Japanese destroyer *Akatsuki*, built by Messrs. Yarrow & Co. The contract for this vessel was signed on the 5th November, 1900; she was launched in just under a year; she ran her preliminary trial the next day, and a week later, on November 14,

she ran her official trial, making 31.3 knots on the measured-mile run, or 31.121 knots in the three hours.

TABLE I.—TORPEDO-BOAT DESTROYERS FOR JAPANESE NAVY, BUILT BY MESSRS. J. I. THORNYCROFT & CO., CHISWICK.

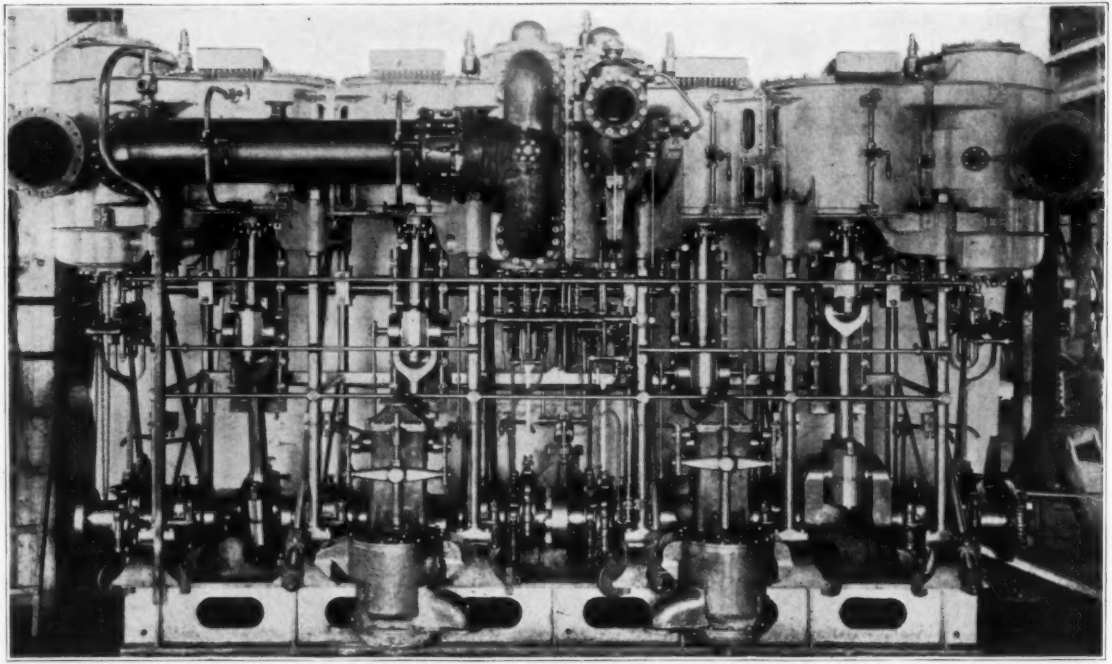
Name.	Where built.	Date when ordered.	Date of launching.	Number of official trials.	Date when accepted.	Number of preliminary trials.
Nurakuwo.....	Thornycroft, Chiswick.	Jan. 15, 1897	Nov. 16, 1898	1	Dec. 24, 1898	2
Shiwowowe.....	Do	Jan. 15, 1897	Dec. 14, 1898	1	Feb. 1, 1899	nil
Yugiri.....	Do	May 7, 1897	Jan. 26, 1899	1	Mar. 10, 1899	"
Shirawui.....	Do	May 7, 1897	Mar. 14, 1899	1	May 6, 1899	"
Kagerou.....	Do	May 6, 1898	Aug. 23, 1899	1	Nov. 14, 1899	"
Usuguwo.....	Do	May 6, 1898	Jan. 16, 1900	1	Feb. 9, 1900	1

TABLE II.—TORPEDO-BOAT DESTROYERS FOR IMPERIAL JAPANESE NAVY, BUILT BY MESSRS. YARROW & CO., POPLAR.

Name.	Where built.	Date when ordered.	Date of launching.	Number of official trials.	Date when accepted.	Number of preliminary trials.
Ikadsuchi...	Yarrow & Co., Limited, Poplar	Jan. 16, 1897	Nov. 15, 1898	3	Feb. 23, 1899	4
Inadsuma..	Do	Jan. 16, 1897	Jan. 28, 1899	1	Apr. 25, 1899	3
Akebono.....	Do	Apr. 30, 1897	Apr. 25, 1899	1	July 3, 1899	1
Sazanami..	Do	Apr. 30, 1897	July 8, 1899	1	Aug. 28, 1899	1
Oboro.....	Do	July 1, 1898	Oct. 5, 1899	1	Nov. 1, 1899	1
Niji.....	Do	July 1, 1898	Dec. 16, 1899	1	Jan. 1, 1900	1

"Naturally, we ought not to compare the trials of the present day with those of a past era, when experience was not so ripe; but making every allowance, one cannot help wondering why it is that even under the most favorable circumstances vessels for the British Navy cannot be built so quickly nor make trials with the same expedition that is attained with the Japanese vessels. We refer more especially to Japanese boats, because the Japanese naval authorities are as strict in all essential details, and are as well informed as those of any other country, not excepting our own. It will be seen that the Thornycroft boats made most of their official trials without even running a preliminary, and all obtained their guaranteed speed of 30 knots—and at times exceeding it by half a knot—on the first trial. Even in the first vessel one additional preliminary trial was sufficient.

"Messrs. Yarrow guaranteed 31 knots for their craft, but only on the first of them was more than one official trial made, and only on the first two more than one preliminary trial. The details of the return and the tables we have added are extremely instructive, and it is to be hoped their publication will do good."



ONE ENGINE OF U. S. DESTROYER "DECATUR."

CONTRACT TRIAL OF THE TORPEDO-BOAT DESTROYER *DECATUR.*

By Commander H. Webster, U. S. Navy.

The *Decatur* is a twin-screw torpedo boat destroyer of 420 tons displacement, and was built by the William R. Trigg Company of Richmond, Va., on the general plan and specifications furnished by the Navy Department. The contract for this boat, together with that for the *Dale*, was signed November 16, 1898, the price being $260,000 each and the time allowed for completion eighteen months.

The price stated above does not include ordnance and ordnance outfit and a few other articles supplied by the Government.

The time for completion of this vessel was afterward extended to April 1, 1902, for various reasons, the principal of which was the difficulty experienced in procuring material.

The speed guaranteed was 28 knots per hour, to be maintained successfully for two consecutive hours, the vessel to be weighted to a displacement of 420 tons. There was no premium provided for excess of speed over that required by the contract, but it was stipulated that a penalty, at the rate of $32,000 per knot, was to be inflicted in case the speed fell below 28 knots. The weight of the machinery was limited to 194 tons, not to include stores and spare parts supplied by the Government, steam steering gear, steam windlass, dynamo engine and torpedo air-compressing machinery.

The penalty for overweight of machinery was $200 per ton in excess of 194 tons, and if this overweight exceeded 5 per cent of the contract weight, then $1,000 additional was to be deducted from the contract price of the vessel.

HULL.

The hull is constructed of mild steel of domestic manufacture, with frames spaced 21 inches apart, except in the engine com-

partments, where they are spaced to suit the engine bed-plate variations. Nickel-steel is used in some places.

The thickness of the keel plate is 12½ pounds per square foot for two-thirds length amidships; forward and abaft of this it is 10 pounds. The vertical keel is 10 pounds per square foot. The outer plating is 9 pounds per square foot and the sheer plating is 12½ pounds per square foot; at the ends it is reduced to 7 pounds forward and 7 pounds astern.

COAL BUNKERS.

There are nine coal bunkers with a total capacity of 210 tons at 43 cubic feet to the ton. There are two hydraulic ash ejectors one fitted in each fire room.

HULL DATA.

Length between perpendiculars, feet	245
on L.W.L., feet	245
over all, feet	250
Beam extreme, feet and inches	23–1½
at L.W.L., feet and inches	23–1½
Ratio of length to beam	10.6 to 1
Beam to top of floor, feet	14
Mean draught, sea-going trim, feet and inches	6–9
Displacement, sea-going trim, tons	450
per inch at L.W.L., tons	4.60
Center of gravity of L.W.L. plane aft of midship section, feet	6.5
Center of buoyancy above bottom of keel, feet	5.75
forward of midship section, feet	3.6
Transverse metacenter above center of buoyancy, feet	6.4
Longitudinal metacenter above center of buoyancy, feet	760.5
Number of frames	141

The battery consists of five 6-pounder semi-automatic rapid-fire guns, two 3-inch 50-caliber rifles, and two Whitehead torpedo tubes, the air compressor for which is of the Bliss type 1–A.

MAIN ENGINES.

There are two vertical, inverted, direct-acting, triple-expansion, four-cylinder engines, placed in separate watertight compartments, the starboard engine forward and the port engine aft.

U. S. DESTROYERS "DALE" AND "DECATUR" IN DRYDOCK.

The cylinder arrangement is as follows: First L.P., H.P., I.P. and second L.P. The second L.P. cylinder is forward in the starboard engine and aft in the port one. The cylinders are supported by vertical, forged-steel, cylindrical columns, stayed by forged and cast-steel ties and braces. Live steam may be admitted to both receivers. The main valves are of the single-ported, piston type, there being for each engine one for the H.P., two for the I.P. and two for each of the L.P. cylinders. The H.P. and I.P. main valves are provided with balance pistons, the cylinders of which form part of the upper covers of the valve chests. The valve gear is of the Stephenson link type, with double-bar links. There are no independent cut-off valves, but provision is made to cut off in each cylinder, varying from five-tenths to seven-tenths of the stroke, by means of a block to which the suspension links are attached, which block can be moved by a hand screw geared in a slot in the end of the arm on the reversing shaft.

The main pistons are steel forgings, dished, and are fitted with two packing rings, each $\frac{1}{2}$ inch wide and $\frac{9}{16}$ inch deep. The piston rods, connecting rods and crossheads are of forged nickel-steel. The go-ahead sliding faces of the crossheads are fitted with white metal. The ahead guide is of cast iron, bolted to the engine frame strongbacks, and is cast hollow for the circulation of water. Composition lips are bolted on each side of the ahead guide to take the thrust when backing. The eccentrics are keyed to the shaft. The eccentric straps are of composition faced with white metal, and the eccentric rods of forged nickel-steel. Each engine-bed plate consists of separate girders, one under each bearing. The reversing gear consists of a steam cylinder with piston acting directly on an arm fixed on the reversing shaft. The valve of this engine is worked by a system of differential levers, the primary motion being derived from the hand lever at the working platform and the secondary motion from a point on the reversing arm. The turning gear consists of a worm wheel on the main shaft worked by a hand ratchet. Each engine is fitted with a throttle valve, 8-inch diameter, single valve, balanced by a steam piston.

ENGINE DATA.

Cylinders, number for each engine	4
H.P., diameter, inches	20½
I.P., diameter, inches	32
L.P. (two), diameter, inches	38
Stroke, inches	22
Valves, H.P. (one for each cylinder), diameter, inches	12
I.P. (two for each cylinder), diameter, inches	12
L.P. (two for each cylinder), diameter, inches	13
Balance pistons, H.P., diameter, inches	5
I.P., diameter, inches	5
Valve stems, H.P., I.P. and L.P., diameter, inches	1¾
through valve, inches	1½
Main steam pipe, diameter, inches	8
exhaust pipe to condenser (two), inches	15½
Piston rods, diameter, inches	4½
length from piston to center of crosshead pin, inches	44½
axial hole, diameter, inches	2¾
Connecting rods, center to center, inches	46⅝
section at upper end, diameter, inches	3⅞
hole, diameter, inches	2½
section at lower end, diameter, inches	4⅛
hole, diameter, inches	2½
Crank-pin bolts (two), diameter, inches	2½
holes in same, inches	1½
Crosshead pins, diameter, inches	5
length of same, inches	7½
axial hole, diameter, inches	2½
Crossheads, wearing surface, ahead, width, inches	11
length, inches	16
backing (two), width, inches	3
length, inches	16

Shafting and Bearings.—The crank, thrust, line and propeller shafting is hollow and of forged nickel-steel. The crank shaft of each engine is in two pieces with the eccentrics keyed on. The cranks of the H.P. and first low pressure are opposite and the intermediate and second L.P. are similarly placed with regard to each other. The H.P. and first L.P. make an angle of 90 degrees with the I.P. and second L.P. and the sequence of cranks is, therefore, H.P., I P., first L.P. and second L.P.

The propeller shafts are covered with a composition casing from the forward coupling to inside the propeller hub.

Engine designed— $\frac{20\frac{1}{2}+32+38+38}{22}$ A. Engine constants—*Decatur.*

	Starboard engine.					Port engine.				
	H.P.	M.P.	1st L.P.	2d L.P.	Total L.P	H.P.	M.P.	1st L.P.	2d L.P.	Total L.P.
Cyl. diam., top, fore and aft	20.518	32.192	38.058	38.029	...	20.596	32.211	38.091	38.023	...
athwart	20.505	32.198	38.024	38.000	...	20.597	32.192	38.066	38.010	...
bottom, fore and aft	20.503	32.198	38.065	38.047	...	20.582	32.195	38.105	38.038	...
athwart	20.501	32.212	38.047	38.034	...	20.584	32.200	38.100	38.031	...
average	20.507	32.200	38.049	38.028	53.606	20.590	32.200	38.091	38.026	53.634
Piston-rod area	15.904	15.904	15.904	15.904	31.808	15.904	15.904	15.904	15.904	31.808
Area head end	330.290	814.334	1137.042	1135.790	2272.832	332.969	814.334	1139.556	1135.670	2275.226
crank end	314.386	798.430	1121.138	1119.886	2241.024	317.065	798.430	1123.652	1119.766	2243.418
Average area	322.338	806.382	1129.090	1127.838	2256.928	325.017	806.382	1131.604	1127.718	2259.322
Ratios, common	1:1.000	1:2.502	1:3.503	1:3.499	1:7.002	1:1.000	1:2.481	1:3.481	1:3.470	1:6.951
Vol. swept by piston, top	7226.380	17915.348	25014.924	24987.380	50002.304	73253.180	17915.348	25070.232	24984.740	50054.972
bottom	6916.492	17565.460	24665.036	24637.492	49302.528	69754.300	17565.460	24720.344	24634.852	49355.196
Average vol. swept by piston	7071.436	17740.404	24839.980	24812.436	49652.416	71503.740	17740.404	24895.288	24809.796	49705.084
Ratio of volumes	1:1.000	1:2.502	1:3.503	1:3.499	1:7.002	1:1.000	1:2.481	1:3.481	1:3.470	1:6.951
Vol. of clearance, top	1642.41	4485.74	6033.63	6128.43	12162.06	1642.41	4485.74	6033.63	6128.43	12162.06
bottom	1832.19	5022.75	6160.77	6245.76	12406.53	1832.19	5022.75	6160.77	6245.76	12406.53
Average vol. of clearance	1737.30	4754.25	6097.20	6187.10	12284.30	1737.30	4754.25	6097.20	6187.10	12284.30
Per cent. of clearance, top	22.73	25.02	24.12	24.15	24.13	22.40	25.00	24.07	24.53	24.30
bottom	26.49	28.58	24.98	25.01	24.99	26.20	28.60	24.91	25.35	25.14
average	24.57	26.80	24.55	24.58	24.56	24.30	26.80	24.49	24.94	24.72
Vol. + clearance, top	8868.790	22401.088	31048.554	31115.810	62164.364	8967.73	22401.09	31103.86	31113.17	62217.03
bottom	8748.682	22588.210	30825.806	30883.252	61709.058	8807.62	22588.21	30881.11	30880.61	61761.73
average	8808.736	22494.649	30937.180	30999.531	61936.711	8887.67	22494.65	30992.49	30996.90	61989.38
Ratio of volumes + clearances	1:1.000	1:2.554	1:3.512	1:3.519	1:7.031	1:1.000	1:2.531	1:3.487	1:3.488	1:7.975
H.P. constant, top	.03666	.09038	.12620	.12608	.25228	.03696	.09040	.12650	.12604	.25254
bottom	.03490	.08862	.12444	.12430	.24874	.03520	.08863	.12572	.12428	.24900
average	.03578	.08950	.12532	.12519	.25051	.03608	.08950	.12561	.12516	.25077

$C.=\frac{L\times A}{16500}$ L. = Stroke in feet. A. = Piston area in sq. in.

The coupling of the stern tube and propeller shafts consists of a forged-steel sleeve 32 inches long, secured by one key lengthwise and two cross keys.

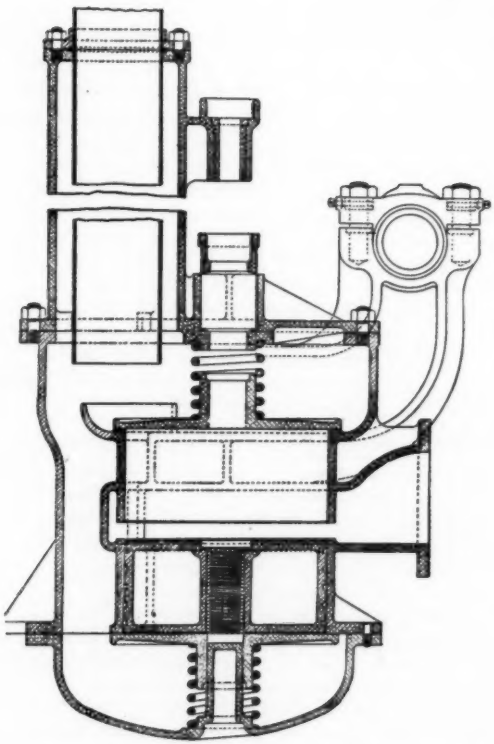
Each thrust bearing is of the collar type, made of cast steel; it is water jacketed and is secured to the framing of the ship. The bearing faces are white metal. There is an oil cup, common to all collars, the white metal being channeled for the distribution of oil.

MATERIAL.—CLASS A NO. 1, MACHINERY FORGINGS.

Crank shaft, diameter, inches	8½
axial hole, diameter, inches	4¼
coupling disc, diameter, inches	15
thickness, inches	2
tapered coupling bolts (eight), inches	1 1/16 to 1⅛
journals, diameter, inches	8½
length (three), inches	11½
length (two), inches	13⅜
length (one), inches	16
Crank pins, diameter, inches	8½
length, inches	12
Crank webs, width, inches	10½
thickness, inches	4½

MATERIAL.—HIGH-GRADE MACHINERY FORGINGS.

Thrust shaft, diameter, inches	7⅞
coupling disc, diameter, inches	15
axial hole, diameter, inches	4¼
collars, number each shaft	11
diameter, inches	11⅛
thickness, inches	1
space between, inches	1¼
length, feet and inches	4- 4¼
Stern-tube shaft, diameter, inches	7⅞
axial hole, diameter, inches	4¼
length, feet and inches	34-11½
Propeller shaft, diameter, inches	7⅞
axial hole, diameter, inches	4¼
length, feet and inches	36- 5⅛
Line shafts, port (one), diameter, inches	7⅞
axial hole, diameter inches	4¼
length, feet and inches	15-11½
Line shafts, starboard (two), diameter, inches	7⅞
axial hole, diameter, inches	4¼
combined length, feet and inches	40-11½



SECTIONAL ELEVATION OF AIR PUMP OF U. S. DESTROYER "DECATUR."
(PISTON SHOWN IN BARREL.)

Stern-bracket bearing, length, inches	27
diameter, inches	8 3/32
Stern-tube bearings, length, forward, inches	37 3/8
aft, inches	25 1/4

Bearings, composition lined with white metal.

Condensers.—There are two main condensers, one for each engine. The shells are of Muntz metal plate, No. 10 B.W.G., made of two cylindrical plates butted together, secured and stiffened by T butt straps of Muntz metal. The water chests are of copper with tube sheets of Muntz metal. The circulating water passes through the tubes. A baffle plate with slots is fitted the entire length of the condenser to direct the steam over the tubes. The inlet pipe is fitted with a small circulating pump to act as supplementary supply to the water forced through the condenser by the speed of the boat.

Diameter of shell, inside, inches	38 1/4
Thickness of shell	No. 10 B.W.G.
Tubes, diameter, inch	4/8
length between tube sheets, inches	73 1/4
thickness No. 18 B.W.G., inch	.049
number in each condenser	1,248
Cooling surface, each condenser, square feet	1,250.4
Cooling surface, total, square feet	2,500.8
Ratio total cooling to total heating surface	.302

Air Pumps.—For each engine there is a single-cylinder double-acting vertical Bailey air pump, worked from an eccentric on the main shaft directly abaft the engine. The eccentric rod actuates a rock shaft, to which arms are attached, and the latter are connected to the air-pump crosshead by double-bar links. A pump valve covers each end of the barrel, and the suction of the pump is through an annular opening at the center of the barrel.

Diameter of pumps, inches	11
Stroke of pump, inches	6
Diameter of pump rod, inches	2
Diameter of rock shaft, inches	3

The air pump is illustrated as constructed and as run on the official trial; but in service it has been found necessary to guide the crosshead in order to overcome a tendency of the piston to

turn and bring undue strain on the links if the connections are slack.

Circulating Pump.—For each main condenser there is a centrifugal double-inlet circulating pump, which is arranged to draw water from the sea, the bilge and main drain, and to discharge into the condenser as a supplemental supply. It is driven by an independent, vertical, single-cylinder engine.

Steam cylinder, diameter, inches	4
Stroke, inches	3
Pump runner, diameter, inches	18
Width at periphery, inches	1⅞
Inlet nozzle, diameter, inches	5⅞
Outlet nozzle, diameter, inches	5

Screw Propellers.—The propellers are of manganese-bronze, tinned, each with three blades. They are true screws, bent back nine inches at the periphery, the starboard one left-handed and the port one right-handed. They turn inboard. They are of the modified Griffiths type. Each propeller is secured to its shaft by a single key and a composition nut screwed on and locked in place.

Number of blades	3
Diameter, feet and inches	7–10
Length of hub, inches	17½
Mean pitch, as set, feet and inches	10.225
Helicoidal area, each screw, square feet	21
Projected area, square feet	16
Disc area, square feet	48.3
Pitch divided by diameter	1.276
Helicoidal area divided by disc area	.434
Projected area divided by disc area	.331
Weight, one propeller, complete, pounds	2,000

Boilers.—There are four Thornycroft water-tubular boilers of Daring type. In this type of boiler there is one steam drum, situated at the apex of an equilateral triangle, and three water drums, one at each of the lower angles and one in the center. The steam drum is connected to each of the water drums by a number of curved tubes for the generation of steam. The steam drum is also connected to the center water drum by fourteen

PROPELLERS OF U. S. TORPEDO-BOAT DESTROYER "DECATUR."

4-inch downtake pipes, situated along the center line of the boiler. The grate bars are of steel, in groups of six. The backs and fronts of the furnaces are built up to the arch of the tubes with fire brick, and on each side to the joint of the tubes with the water drum; each boiler is bolted to angle irons, which are riveted to the saddles. The boiler is covered with a casing consisting of $\frac{1}{4}$-inch sheet asbestos, and outside of that a $\frac{3}{4}$-inch sheet of non-conducting material, the whole protected by sections of light galvanized steel plate of such size as to be easily removable while the boiler is in place. There are two furnaces to a boiler, the shape of which is fixed by the arch of the tubes; there are two doors to a furnace. In the steam drum is a Thornycroft automatic feed regulator, which is operated by the variation in the height of the water. The circulation of the water is up the small curved tubes to the steam drum and then down the center water tubes and some of the small steam tubes to the water drums. Each boiler has two 4-inch safety valves, placed on the stop-valve nozzles, the two valves being in one case.

There is a fire extinguisher situated over each furnace. The boiler tubes are of solid drawn steel. The boilers are placed fore and aft in two watertight compartments. There are two boilers in a single compartment forward of the engines, and two boilers in a compartment abaft the engines, these latter boilers being located over the shafting. There are four smoke pipes—one for each boiler.

BOILER DATA.

Steam pressure, designed, pounds	300
at engine, pounds	250
Number of boilers	4
Length of steam drum, feet	11
Width over casing, 3 after boilers, feet and inches	15–8
1 forward boiler	14–8
Height, feet and inches	10–4
Steam drum, diameter inside, inches	37
thickness, inch	1
Water drums, diameter, inside, inches	19
thickness, inch	$\frac{5}{8}$
Furnaces, width grate, 3 after boilers, feet and inches	5–3

Furnaces, width grate, 1 forward boiler, feet and inches	5–9
length grate, feet and inches	7–0
Number of furnace doors	4
Tubes, diameter, inches	1⅝ and 1¾
number 1⅝ inch	1,346
1¾ inch	372
thickness	No. 11 B.W.G.
Heating surface tubes, 4 boilers, square feet	17,768
Grate surface, 4 boilers, square feet	315
Ratio H.S. to G.S.	56.4 : 1
Smoke pipes, (4) diameter (oval), feet and inches	4–7 × 2–6
area, each, square feet	10.1
total area of 4 pipes, square feet	40.4
Ratio of pipe area to G.S.	1 : 7.8
Height above lower grate, feet	27.6
Safety valves (2), diameter, each, inches	4
Main stop valve, diameter, inches	8

Forced Draft.—The closed fire-room system of forced draft is used. The air is supplied by four blowers, made by W. D. Forbes, two in the forward and two in the after fire room. The fans are driven by simple enclosed engines, set horizontally.

Cylinders (2), diameter, inches	4½
Stroke, inches	5
Fan, diameter, inches	54
width at rim, inches	14
area of induction nozzle, square inches	1,017.9
area of eduction nozzle, square inches	3,875
Revolutions to maintain air pressure of 4½ inches	700

Feed Pumps.—There are four main and two auxiliary feed pumps of the Blake vertical, single-cylinder type, all of the same size, 10 inches by 6 inches by 12 inches. The main feed pumps are located, one in the after engine room, one in the forward engine room, one in the forward fire room and one in the after fire room, and draw from the feed tanks, the reserve feed tanks and air-pump suctions, and deliver to the boilers and reserve feed tanks. The auxiliary feed pumps are situated in the forward and after fire rooms and draw from the feed tanks, reserve feed tanks, the sea, the drainage system and boilers, and discharge into the boilers, the fire main and overboard.

Fire and Bilge Pumps.—In the after engine room there is a

Blake vertical, single-cylinder pump, which draws from the sea, bilge and drainage system, and delivers into the fire main and overboard. The steam cylinder is 6 inches, the water cylinder 8 inches and the stroke 12 inches.

Water-Service Pump.—The distiller pump in the after fire room is used for this purpose. The water service can also be taken from the condenser.

Feed Tanks.—There is a feed tank of 200 gallons capacity in each engine room, from which the water flows by gravity to the pumps. A part of the tank is fitted as a filter, into which water from the air pumps is delivered. The water descends through the filtering material and discharges into the main portion of the tank; each tank has a hinged lid and a glass water gauge. Each tank and filter has the following pipe connections: A discharge pipe from the air pump, an overflow pipe to the bilge, a suction pipe to feed pump, a vapor pipe and drain pipe from traps.

Steam Traps.—The separators, jackets, main and auxiliary steam pipes, steam-heating system and all places where condensed steam can accumulate, are fitted with drain pipes and cocks, or valves, and with automatic traps, which discharge into the feed tanks. The traps are provided with by-pass pipes and valves for convenience in overhauling.

Steam Ejectors.—There is a steam ejector in each engine and fire room for freeing the bilge of oil or water. They have a capacity of 2,000 gallons per hour.

Distilling Apparatus.—In the after engine room there are two evaporators and one distiller of the Baird-Davidson type, with a combined capacity of 3,000 gallons of potable water in twenty-four hours at a temperature of 90 degrees Fahrenheit. The distillers are arranged so that they can take steam from the auxiliary pipe in case of emergency. There is one single-cylinder distiller pump $3\frac{1}{2}$ by $4\frac{3}{4}$ by 4 and one evaporator feed pump of the Blake duplex type, 2 inches by $1\frac{1}{2}$ inches by $2\frac{1}{2}$ inches. The distiller has 16 square feet of cooling surface, and each evaporator 65 square feet of heating surface.

Air Compressor.—There is one air compressor for the torpedoes. It is the Bliss type 1–A, and on trial, with 150 pounds boiler

pressure, supplied air at 1,500 pounds pressure in seven minutes throughout the entire torpedo outfit of piping.

Telegraph and Revolution Indicators.—There is a Cory mechanical telegraph in each engine room connected to transmitters in forward and after conning towers. Mechanical tell-tales are fitted in the forward conning tower to show the direction and speed of revolutions of the main engines. In each engine room there is a mechanical revolution counter.

Voice Tubes.—For communication between the conning towers, torpedo-tube stations and engine rooms, there are voice tubes with electric call bells.

Electric Plant.—The installation consists in general of one 5-kilowatt generating set, ninety-five incandescent lights, one searchlight, one set of signalling apparatus, one main switchboard, together with the necessary wiring, wiring accessories, conduits and fixtures.

The generating set was made by the General Electric Company, and consists of one 5-kilowatt dynamo of mutipolar type with a capacity of 62.5 ampères at eighty volts, compound wound, six poles. The dynamo engine is of the single-cylinder, vertical type; diameter of cylinders 4 inches, by 4-inch stroke. The engine is designed to run under full load at 700 revolutions per minute with eighty pounds steam pressure. The bedplate is common to both engine and dynamo. The incandescent lights are of 5 and 16-candle power, designed for a potential of eighty volts. The dynamo is connected to the switchboard through suitable leads protected by steel conduits. The switchboard is equipped with one main dynamo switch and four circuit switches, two Weston round-pattern switchboard voltmeters, together with the usual rheostats, pilot lamps and ground detectors. The vessel is wired on the two-wire system.

There is one 18-inch hand-controlled searchlight, made by the General Electric Company, mounted over forward bridge and in circuit with a suitable rheostat mounted on the main switchboard.

Annunciators, press buttons and bells are provided in connection with voice tubes, for communication between the conning towers and the various compartments of the vessel.

MACHINERY WEIGHTS IN POUNDS.

	Dry.	*Wet.*
Engine-room and stern weights	197,508	210,190
Forward fire-room weights	102,210	117,210
After fire-room weights	101,988	116,988
Tools, stores, miscellaneous machinery	...	6,440
Total weight		450,828

DETAILED WEIGHTS FOR TWO ENGINES.

Cylinders and fittings, pounds	44,102
Shafting, pounds	31,443
Reciprocating parts, pounds	9,850
Framing, bed plates and bearings, pounds	31,306
Valves and valve gear, pounds	8,376
Condensers, pounds	17,230
Air and circulating pumps, pounds	6,024
Boiler, fittings and up-takes (four boilers), pounds	143,636
Smoke pipes, pounds	12,700

PIPING AND MISCELLANEOUS.

Steam, exhaust, suction, discharge pipes and valves, pounds	36,406
Lagging and clothing, pounds	25,652
Floor plates, pounds	4,788
Auxiliaries, pounds	15,856
Fittings and gear, pounds	10,130
Water, pounds	42,682

The average tensile strengths of the various materials used on these boats are as follows:

	Tensile.	*Minimum elastic limit.*
Forged steel:		
Engine, main parts, except crank shaft,	95,000	65,000
Columns, stays, pistons	80,000	50,000
Handgear, etc	80,000	45,000
Ordinary forgings	60,000	30,000
Cast steel:		*Per cent. elongation in 8 inches.*
Subject to shock	60,000	15
Not subject to shock	70,000	10
Composition, 88 Cu. 10 Zn. 2 Sn	34,000	14
Brazing metal, 90 Cu. 2 Zn. 8 Sn	28,000	20
	Tensile.	*Minimum elastic limit.*
Manganese-bronze	70,000	40,000
Copper pipe, hydraulic test	6,000	.....
Brass pipe, hydraulic test	7,000	.....
Tobin bronze, rolled rods	60,000	30,000
Phosphor-bronze, rolled rods	40,000	.....

THE TRIAL.

The official trial of the *Decatur* was held on the Barren Island course, fifty miles below Annapolis, Md.

The boat was required to undergo two trials; the first a standardization-screw trial, and the second a two-hour run at full speed, at the average number of revolutions necessary for a speed of 28 knots, as determined by the standardization of the screw on the previous trial.

The engineers and firemen were thoroughly experienced in this class of work, and were under the supervision of Mr. Geo. F. Coleman, who had conducted the trials of the *Stockton* and *Shubrick*, torpedo boats built by the William R. Trigg Company, and the first of the torpedo boats built under the act of Congress of 1898 to be accepted by the Navy Department.

The boat had passed the preliminary trial of the contractors very successfully.

The progressive-speed trial of the *Decatur* for the standardization of the propellers, over the measured-mile course, was held December 10, 1901.

The conditions of wind and sea were favorable. The several double runs were made as nearly as practicable at the rates of speed prescribed by the precept for the trial. At a signal given by the observer, who marked with a stop watch the time of passing the range marks placed at the ends of the measured-mile course, the two counters were thrown into gear at the moment of entering and out of gear at the moment of leaving the course. Readings of the engine-room gauges were taken and recorded during each run. The points obtained from the observed revolutions of the engines and the corresponding speeds of the vessel on the measured mile were used to determine the revolutions necessary for a speed of 28 knots.

The trial was conducted by the Naval Board of Inspection and Survey, composed of Captain C. J. Train, U. S. N., President; Naval Constructor J. J. Woodward, U. S. N.; Commander C. R. Roelker, U. S. N.; Commander C. E. Vreeland, U. S. N.; Lieutenant Commander T. F. Rodgers, U. S. N., Recorder. Commander Harrie Webster, U. S. N.; Lieutenant A. S. Halstead,

STANDARDIZATION TRIAL—*DECATUR*.

Direction.		1st double run.		2d double run.		3d double run.		4th double run.	
		South.	North.	South.	North.	South.	North.	South.	North.
Duration		2'42.2	2'36	2'20.5	2'20.4	2'17.4	2'11	2'08.6	2'06.4
Mean speed of double run		22.638		25.632		26.841		28.228	
Total revolutions during each run	P.	696	692	696	697	696	697	696	705
	S.	682	702	709	706	707	706	706	710
Mean revolutions per minute during double run		261.50		299.85		313.85		331.45	
Mean apparent slip of screws, per cent		12.44		13.54		13.51		13.87	
Steam at engine	P.	132	135.3	179	178	186.3	210	219.3	228
	S.	137	139	181	180	193.3	218.6	230	236.6
Steam in first receiver	P.	54.3	55.3	75.0	74.3	79.0	91	95	86.3
	S.	42	42	58	58	62.3	70.3	72.3	75.0
Steam in second receiver	P.	4.3	4.6	10.3	10.3	11.5	15.2	15.8	18.0
	S.	0	2.0	6.6	7.0	9.0	11.3	12.0	13.3
Vacuum	P.	27.5	27.5	27.9	27.7	27.5	27.1	26.5	26.3
	S.	27.5	27.5	27.5	27.5	27.5	27.5	27.5	27.5

The total time elapsed between the beginning of the first run and the end of the fourth double run was sixty-eight minutes. Conditions of wind and sea were favorable. Mean displacement during this trial was four hundred and fifty tons.

U. S. N., and Assistant Surgeon A. M. Fauntleroy reported to the President for duty in connection with the trial.

The results of the runs with and against the tide having been plotted as separate curves, the mean curve of true speed of vessel and engine revolutions was obtained from which it was determined that a mean speed of both engines of 328.7 revolutions per minute is required for a true speed of vessel of 28 knots.

Corresponding apparent slip of screws was 13.85 per cent.

On the afternoon of December 12, 1901, the *Decatur* left Solomon's Island for the purpose of running the full two-hour contract-speed trial. The conditions of wind and sea were favorable.

The trial lasted exactly two hours. The counter readings were recorded every five minutes. The observed data are given in the following tables.

Time—P.M.	Mean revolutions per minute.	Steam pressure above atmosphere.			Vacuum.
		At engine.	First receiver.	Second receiver.	
		STARBOARD ENGINE.			
2'47	0.	230	70	12	28
3'02	328.	235	73	12	28
3'17	329.66	235	75	13	28
3'32	334.33	235	72	14	28
3'47	335.33	225	73	13	28
4'02	331.33	230	74	13	28
4'17	332.60	225	71	13	28
4'32	328.80	230	72	14	28
4'47	334.07	230	71	13	28
Mean	331.775	230.5	72.3	13	28
		PORT ENGINE.			
2'47	0	212	65	11.5	27.5
3'02	324.67	220	67	12	27
3'17	327.67	225	70	14	26.5
3'32	331.00	225	68	13	26.5
3'47	333.67	220	67	13	26.5
4'02	327.33	220	67	13	26.5
4'17	328.00	220	67	13	27
4.32	324.00	215	65	12	28
4'47	330.00	220	65	12	28
Mean	328.292	219.7	66.8	12.6	27.5

Mean revolutions per minute of both engines maintained for two consecutive hours, 330.0335.

Mean speed of vessel, 28.10 knots.

The coal used during the full-power speed trial was hand-picked Pocahontas of excellent quality, supplied to the fire room in bags weighed by the contractors.

It will be noted that the *Decatur* fulfilled her contract requirements on 25 pounds steam less than she was allowed to carry by contract.

The average air pressure was about 5 inches.

There was practically no vibration of the engines at any speed. Their working indicated that they were well balanced, framing stiff and foundations strongly built. After the two-hour speed trial, turning trials were made at a speed of about twenty-three knots.

The time taken by the steering engine in putting the helm from amidship to hard a-port was $4\frac{2}{5}$ seconds, and the estimated diameter of the turning circle was 330 yards.

The sea-going qualities of the *Decatur*, as far as could be observed during a trial in smooth water, are excellent.

The change of trim while at full speed was estimated to be, at a speed of 28 knots, about 3 feet.

The local vibration of the outside plating in the wake of the propellers was at no time excessive.

THE WATER-TUBE BOILER QUESTION IN THE GERMAN NAVY.

By Köhn von Jaski, Marine-Oberbaurath.

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I.—ORIGIN OF THE WATER-TUBE BOILER QUESTION.

The rivalry between ships' guns and armor and the endeavors which are constantly being made to increase the speed and extend the radius of action of war ships have added so greatly to the weights that have to be carried by ships that it has become a matter of grave concern to save weight wherever it can be done, if the displacements are not to become unduly large, and the cost of construction is to be kept within the limits of the amount placed at the disposal of the constructors for naval purposes.

Up to a certain point it has been possible to lessen the weight of the guns by improved methods of construction, and the weight of the armor by making it of better material; the weight of the coal required has also been diminished by more economical engines. The use of mild steel (*flusseisen*) of greater strength has allowed of a reduction being made in the dimensions of a number of constructive details which, as a consequence, has admitted of not only the larger engines now required, but also of the hulls being built relatively lighter than was formerly possible, *e. g.*, the actual weights of the hulls of the old armored ships *Kônig Wilhelm*, *Kaiser* and *Deutschland*, when they were built varied between 44.96 and 38.86 per cent. of their total displacements, whereas the actual weight of hull to total displacement in the new battleship *Kaiser Friedrich III* is only 31.64 per cent. The saving in weight, however, was still insufficient. The heavy guns of large caliber were replaced by lighter and more efficient guns of smaller calibers, and by Q.F. guns. A short 30.5-centi-

meter (12-inch) hooped gun, with a striking energy of 4,680 meter-tons (15,112 foot-tons), weighed 36 tons, whereas a modern long 24-centimeter (9.45-inch) gun, with a total striking energy of 4,349 meter-tons (14,043 foot-tons), weighs only 25.8 tons; being thus 30 per cent. lighter, with a diminution of only 7 per cent. of energy. The new arrangement, moreover, allows of a greater number of guns with hydraulic training gear and a much larger amount of ammunition being put on board, so that the proportion of the weight of the gunnery and torpedo armament to the total displacement is not really less. Thus, whilst the weight of the guns in the old armored ships *Kaiser* and *Deutschland* was 6.74 per cent. and in the *König Wilhelm* 8.21 per cent. of the total displacements, the percentages in the battleship *Kaiser Friedrich III* are 7.42 per cent. for the guns, and 1.05 per cent. for the torpedo armament, making a total of 8.47 per cent. for gunnery and torpedo armaments combined.

The improvements in armor allowed of thinner, and, consequently, lighter plates for a given resistance being substituted; but, at the same time, the protection had to be increased correspondingly with the greater penetration acquired by the enemy's projectiles; the heavy guns, therefore, had to be protected by armored turrets, the ammunition hoists had also to be armored, and the main engines and boilers likewise necessitated the addition of protective decks; hence the weight of armor had to be considerably increased. Thus, whilst the weight of armor in the older ships was only 21.82 per cent. in the *König Wilhelm*, and 23.14 in the *Kaiser* and in the *Deutschland*, the percentage in the battleship *Kaiser Friedrich III* rose to 34.31 per cent. of the total displacement. Then, again, the demand for greater speed led to a distinct increase in the weight of the machinery installations, and to an ever-increasing percentage of the total displacement being required to meet it. Thus, the percentages of the weights for engines and boilers to the total displacements of the ships named are as follows for the older ships: *König Wilhelm*, 11 per cent.; *Siegfried*, 10.9 per cent., and *Sachsen*, before reconstruction, 13.3 per cent.; as against, for the newer ships *Prinzess Wilhelm*, 20.8 per cent.; *Kaiserin Augusta*, 23.7 per cent.; *Jagd*, 24.6 per

cent., and *Meteor*, 26.2 per cent. The task, therefore, imposed upon the engine makers for warships was how to obtain further economy in the weight of the machinery installations.

This demand was all the more difficult to meet, by reason of the introduction of increased expansion of the steam, which, whilst it diminished the consumption of coal, and, consequently, increased the radius of action of ships, led to the employment of higher-pressure steam. This had necessarily to be followed by increased strength of all such parts of the machinery as are subject to steam pressure, more especially in the plates of the large cylindrical boilers, all of which meant considerable increase in the weight of the boiler installations.

At first an attempt was made to obtain a large amount of steam from small boilers by forced draft, but the cylindrical and locomotive types of boilers, which were then generally used, proved but little suited for the purpose. When steaming under natural draft the layer of coal on the bars is kept thin, and the products of combustion are diluted with a large excess of air. Owing to this the temperature in the furnace is kept comparatively low. Under these conditions only a small quantity of heat per unit of time is transferred to the water in the boiler through the plates of the furnaces and combustion chambers. But, when steaming under forced draft, the fires are kept very thick, and this, together with careful stoking, allows very little more air to pass through than is theoretically required for the combustion of the fuel; consequently the temperature in the furnace is much higher than with natural draft, and a large amount of heat per unit of time is transferred to the water in the boiler through the plates of the furnaces and combustion chambers. These plates will, consequently, become much hotter than when steaming with natural draft, whilst the rigid construction of the cylindrical and locomotive boilers does not allow of the increased expansion due to the higher temperature of the plates taking place. The effect of heat on the various parts of boilers is as follows: The shell of the boiler is heated to the temperature of the steam, that is to say, with a steam pressure of 12 kilogrammes per square centimeter (170 pounds per square inch) to

190 degrees centigrade (374 degrees Fahrenheit), the furnace sheets, however, under forced draft, and with the fires properly stoked, attain a temperature of from 360 degrees to 400 degrees centigrade (680 degrees to 752 degrees Fahrenheit). If the temperature of the furnace plates is taken as being only 370 degrees centigrade, the furnace sheets are thus 370° — 190° = 180° C. (356° F.) hotter than the shell plates, and, consequently, with a coefficient of expansion of 0.0000123 and a length of furnace, say, of 2,400 millimeters, would, if free, expand some 180 × 0.0000123 × 2,400 = 5.3 millimeters (.209 inch) more than the boiler shell plates. As, however, the necessary fixing of the front end of the boiler does not admit of this large expansion of the furnace plates inside, this expansion — taking the size of the furnace box of a locomotive boiler as being 4,400 millimeters (14 feet 5.23 inches) and the thickness of the plates as 16 millimeters (.63 inch), as would be about right for ships' boilers, and the coefficient of elasticity as 21,500 — means a stress on the rivet seams of the furnace and on the tube joints in the back tube plate, which on the calculation $P = \frac{21{,}500 \times 4{,}400 \times 16 \times 5.3}{2{,}400}$ is equal to 3,038,700 kilogrammes (3,090 tons). It is clear that no riveted seam can withstand such a stress for any length of time, and still less the joints of the tubes in the tube plates. For this reason, the furnaces in cylindrical boilers are made of corrugated plates, which alter their form under the expansion due to the heat; the resistance, however, which a corrugated tube opposes to this change of form is still very considerable, and the stress arising in the longitudinal direction of the furnaces must be taken up by the riveted seams; whilst this expansion stress also affects the tightness of the joints of the tubes in the tube plates. As a consequence, such frequent and heavy leakages occurred in the furnace seams and at the tube plate that any heavy forcing of this boiler had to be abandoned.

Here again, therefore, the construction of ships' machinery soon came to a full stop, and it became a matter of necessity to drop the present system of boiler construction if a further saving in weight was to be effected.

That considerable saving in weight in the boiler installations could be obtained by substituting water-tube for the heavy cylindrical and locomotive types of boilers was well known to experts; but previous experiments which had been made with boilers of this type had invariably to be discontinued because of the disadvantages which then attended the use of water-tube boilers, and which appeared to be insurmountable. The same constructors of machinery for war ships, who at first fought against the introduction of water tube boilers, have, however, in the search after lighter installations, been forced step by step to give way, until now their construction is perforce being accepted in all Navies. It is true that such a decision has not been arrived at without much searchings of heart, for the constructors were well aware of the fundamental disadvantages of these boilers, and that in adopting them they would have to contend against the force of habit and the prejudices of the *personnel* against the innovation. After deciding upon their introduction there followed a series of experiments with the various types of water-tube boilers most in favor, with a view to selecting such types as were most suitable for use on board ships of war; these experiments were, of course, characterized by the sceptics as failures on the part of the constructors, whilst the cylindrical and locomotive types were proclaimed as being the only suitable types, if only they were not forced too much.

II.—OTHER REASONS FOR THE INTRODUCTION OF WATER-TUBE BOILERS.

Among other reasons telling largely in favor of the introduction of water-tube boilers on board ships of war were the following:—

1. *Ability to Raise Steam Quickly.*—The cylindrical and locomotive boilers hitherto used are not only very sensitive to forced draft, but also to quick raising of steam, as their larger water capacity necessitates more coal being burnt in raising steam, because of the large amount of heat required to heat up the water; for instance, the ships of the *Brandenburg* class with the water in their boilers cold before lighting the fires, require, if

there is no special hurry, and the boilers can consequently be considered, to have the fires burning for eight hours before the ships can go at full speed, and only in case of necessity can steam be raised in from three to four hours in a cylindrical boiler filled with cold water. In war time, especially on blockading service, it will, however, often be necessary to keep the ships lying to for considerable periods, and yet to have them ready to start at the shortest notice. In order to save coal it is desirable that the fires should be out whilst the ship is stationary, but if three to four hours are required to raise steam, and before she can be ready to start, it would be necessary to keep the fires banked. According to experiments carried out by H. I. M. S. *Kurfürst Friedrich Wilhelm*, during the summer of 1899, the coal consumption for this must be calculated at the rate of 200 kilogrammes per square meter (40.96 pounds per square foot) of grate area per day, so that for a ship with twelve boilers each having a grate area of 5.85 square meters (54.7 square feet)—two boilers having steam up and ten being banked—the daily coal consumption would amount to $58.5 \times 2.0 = 11.7$, or roughly, about 12 tons. In order to try and diminish this heavy coal consumption, the first squadron during the same summer successfully tried the experiment of keeping the water hot in the boilers not in use, by injecting steam into the water of those at rest with the hydrokineter worked from the boilers kept under steam for driving the dynamos and auxiliary engines. To do this for five days in six boilers, the coal consumed per day was only 3.65 tons; consequently in order to keep the water hot in ten boilers the consumption would be $\frac{10 \times 3.65}{6} = 6$ tons per day, or just one-half the amount required for keeping the fires banked. In any case, however, if the ship has to remain stationary for any considerable time, the coal consumption in a ship fitted with water-tube boilers is less than in one with cylindrical boilers. According to the experiments carried out by H. I. M. S. *Ægir*, in order to raise steam in water-tube boilers with a grate area of 58.5 square meters, when the water has quite cooled down, some fourteen tons of coal are required; after lying to,

therefore, for 2⅓ days, there would already be an advantage in raising fresh steam in water-tube boilers rather than in keeping the water in cylindrical boilers hot by means of hydrokineters.

With cylindrical boilers where the water has been kept at the boiling point by the hydrokineter used in connection with the other boilers, it is possible to raise steam in from fifty to seventy-five minutes. With water-tube boilers steam can be raised in twenty-five minutes without endangering the boiler; it must, however, be borne in mind that large ships' engines, with their long steam pipes, after lying for some days at rest, cannot be sufficiently warmed up in twenty-five minutes to allow the engines to be started. About one hour is required after the engines have been at rest for a long time before all the parts have become sufficiently warm as to obviate all fear of water-shock in the steam pipes and cylinders. In order to be ready to start at half an hour's notice, several boilers must be kept under steam, and the engines must be kept warmed even when a ship has water-tube boilers.

2. *Facility in Changing the Speed.*—Just as it is possible with water-tube boilers to raise steam more quickly than with cylindrical or locomotive boilers, so also is it possible to carry out quicker changes in the speed of the engines. Mention has already been made of the great stress on the boiler connections, *i. e.*, on the riveted seams, and on the joints of the boiler tubes in the tube plates through the expansion of the furnaces built into the outer shell of cylindrical and locomotive boilers. Of still greater danger to these connections, however, are the partial or local overheating and cooling of the furnaces, caused by the grate being unevenly covered with coal, for it is just through the alternate expansions and contractions of the plates, especially when they occur irregularly in different places, that the connections work loose. If the speed of the engines is suddenly increased, the forcing of the boilers has to be similarly suddenly increased, and then the danger becomes greater, because a higher air pressure is obtained before the grate is covered with a uniformly thick layer of coal. This is also the reason why, when forced draft is used with cylindrical and locomotive boilers,

the fires have to be kept thick; whereas the less sensitive water-tube boilers are always heated with thin fires even under high forced draft.

3. *Facility in Erecting and Taking to Pieces.*—Large cylindrical and locomotive boilers are very difficult to fit in place on board and to take out again. If it becomes necessary to remove a boiler to effect large repairs in the shop, or if a boiler has to be replaced by a new one, the whole of the deck over the boiler in question has to be taken up, and a very considerable disturbance of fittings takes place. On the other hand, a water-tube boiler can be taken to pieces in the boiler room, and, after renewing any of its parts, it can be completely built up again in place.

4. *Less Danger from Explosion.*—Explosions in water-tube boilers are less dangerous than in cylindrical and locomotive boilers. If the working of the boiler is carefully supervised, and if the boiler is subjected to regular and adequate inspection, barring extraneous causes, there is little reason to fear any defect of the plates in cylindrical and locomotive boilers, but the want of water has too often been proved to be the cause of accidents in the working of ships' boilers. When such is the case the crown of the combustion chamber becomes red hot, and this is followed by the stays drawing out of it. If under such circumstances the combustion chamber crown does not split, such an amount of steam pours out from the holes made in it that excessive pressures take place in the furnace, and the furnace doors are blown out, and the stokers are scalded. Accidents of this sort occurred in 1892 to divisional torpedo-boat *D 5*, and in 1899 on board H. I. M. S. *Wacht.* With water-tube boilers, on the other hand, the cylindrical-shaped steam collectors are the highest parts containing water, and these are either not exposed to the fire or are reached only by the comparatively cooled gases. Even, however, if the plates of this steam collector, which in small tube water-tube boilers also form the tube walls, should become red hot from a prolonged absence of water, and some of the water tubes should draw out, the steam outlets caused thereby would be so close to the uptake that the greater part of the steam would escape through the funnel, and would only

enter the stokehold if the furnace door were open. In any case the small amount of water would be quickly evaporated, and the small quantity of steam which might enter the stokehold could not be as disastrous in its effects as the steam coming from a cylindrical boiler in which the quantity of water is four or five times greater. This difference will be specially emphasized if a boiler or steam pipe inside the boiler room should be shot away in action. In such case the sudden escape of high-pressure steam would prevent the stop valves to the other boilers from being closed, and the whole of the steam from the other boilers directly connected with the damaged boiler or steam pipe would escape into the boiler room. Even if the shot striking the boiler should not bring about a disastrous explosion involving the whole ship—as seems probable from the experience of cylindrical boilers exploding when working on shore—the large amount of steam escaping from the boilers would drive in the boiler-room bulkheads, and probably involve other parts of the ship. The disastrous effects caused by water-tube boilers with one-fourth or one-fifth the amount of steam would certainly be smaller.

III.—DISADVANTAGES OF WATER-TUBE BOILERS.

Against the foregoing remarks telling in favor of water-tube boilers when compared with cylindrical and locomotive boilers, there must, however, be placed various peculiarities inherent to these boilers which are very inconvenient when working on board ship.

1. *Necessity for Regular Feeding.*—The advantages attending the small water chambers of water-tube boilers have been referred to in II, 1 and 4, but this small supply of water has, on the other hand, the attendant disadvantage that there is no reserve to equalize slight irregularities in the feeding, and that the rate of feeding must be very quickly altered when the output of steam from the boiler is increased, as otherwise shortness of water will occur.

Water-tube boilers consequently need very careful feeding, and very complicated automatic feed-water regulators, which must

be carefully attended to and closely watched, as they often have to be adjusted by hand under varying conditions of forcing.

The regulator which is often placed in the steam collector greatly restricts the available space in the collector, and leads, if made of bronze, to galvanic action being set up, which tends to wear away the boiler plates. Even when the feed regulator is arranged outside, for which there is not always room available, the action of the float is liable to be irregular when changes are made in the rate of evaporation in the boiler. Regulating the feed of water-tube boilers by hand, however, is hardly possible because of the changing speeds of the engines and the somewhat irregular stoking of the fires.

2. *Necessity for Regular Stoking.*—Just as is the case in regard to the water spaces, so also the steam spaces in water-tube boilers are small, often to the extent of being only one-fourth of the capacity of cylindrical boilers having the same amount of grate area. As a consequence the reserve of steam is insufficient to compensate for slight irregularities in the management of the fires and in the speed of the engines. In order to restrict these irregularities as much as possible a special system of stoking has been devised by which the fires are kept very thin—4 to 5 inches thick only—even when heavily forced, and regular intervals are laid down for stokers to fire up corresponding with the amount of forcing employed. The amount of coal thrown on at a time is some 1.64 pounds per square foot of grate area; hence, if under forced draft and burning 32.27 pounds per square foot per hour, the furnaces have to be fed twenty times an hour. There is thus an interval of only three minutes between each stoking, and although but a few shovels full have to be thrown on at a time the stokers scarcely obtain any rest, and the labor is consequently very much more irksome than when longer intervals occur. Moreover, not taking into account the management of locomotive boilers on board torpedo boats, much greater forced draft is used with water-tube boilers as a rule than with cylindrical and locomotive boilers; hence more coal is used per foot of grate area per hour, and equally, of course, per furnace per hour, thereby exacting greater exertions from the individual stoker. As a

matter of fact, this excessive labor is not so much to be laid to the charge of the nature of water-tube boilers themselves as to the fact that their construction renders possible a greater forcing of the fires.

In order to keep the fires uniformly thin, more skilled stoking is required than to keep thick fires. The *personnel* consequently needs to be specially trained in the management of water-tube boilers, and unless the stokers are properly trained full efficiency in the boilers cannot be relied upon. With a *personnel* coming fresh on board who are unaccustomed to the management of water-tube boilers, irregular working is pretty sure to occur; whereas the stokers who join the Navy from the mercantile marine are necessarily familiar with the management of cylindrical boilers.

3. Necessity of Keeping Water Surfaces Clean.—Any steam boiler becomes endangered if the conductivity of the heating surfaces, or of individual parts of these surfaces, is too much reduced through the fouling of the water-washed sides, for the heat impinging from the fire on the boiler walls being no longer able to pass to the boiler water causes the walls to become red hot. The materials used in the construction of boilers when they become red hot possess very little strength, and, as a consequence, when the walls attain this condition they are no longer able to withstand the pressure of the steam. Whereas, however, the thin tubes in cylindrical and locomotive boilers derive assistance from the surrounding water under the steam pressure, the effect of the pressure inside the thin tubes of water-tube boilers is to cause them to burst. If, therefore, fire tubes get red hot they become flattened, CO, and although leakage may take place at the joints of the tubes in the tube plates, no large openings are made for the escape of the water in the boiler. On the other hand, in water-tube boilers red-hot water tubes burst, and it is then impossible to prevent practically the whole of the water and steam in the boiler from being blown into the furnace, which may lead to the stokers being scalded if the furnace doors are not kept shut. In any case, however, when a tube bursts, the water-tube boiler becomes unworkable until the defective tube can be

replaced by a new one, or, in the case of small-tube water-tube boilers, until the hole in the tube plate can be stopped. The danger of explosion consequent on foulness of the inner heating surfaces is thus considerably greater in water-tube boilers than in cylindrical or locomotive boilers. There is truth, therefore, in the saying that water-tube boilers are very sensitive to impure feed water.

4. Difficulty of Cleaning the Water Surfaces.—Small-tube water-tube boilers are difficult to clean because the tubes are not easily accessible. Curved tubes especially cannot be examined, and it is therefore not possible to ascertain whether the tubes are quite clean inside. Large-tube boilers, on the other hand, can be thoroughly cleaned and examined, but they have a large number of separate doors, and, therefore, take up much time and labor in cleaning. The numerous screwed connections also give rise to frequent repairs.

IV.—CHOICE OF TYPE OF WATER-TUBE BOILER.

As soon as our naval constructors had decided, after weighing the pros and cons referred to in I, II and III, to place water-tube boilers in our warships, the difficult question arose as to which of the then known types should be adopted.

1. Rigid Constructions.—After what has been said in I and II as to the great sensitiveness of cylindrical and locomotive boilers under heavy forcing of the fires, quick raising of steam, and irregularities in the management of the fires, all water-tube boilers were at once excluded whose tubes, like the fire tubes in these boilers, are rigidly fixed between stationary water chambers. As it was a matter of rendering feasible heavy forced draft and sudden changes in the condition of the fires without risk of leakage occurring in the tube joints, there could be no question of employing the D'Allest, Steinmüller, Heine, or any other similar boilers which may possibly be quite satisfactory water-tube boilers under other conditions of service. It is true that in the French Navy the *Charles Martel*, the *Carnot*, the *Du Chayla*, the *Cassard*, the *Kersaint*, the *Jauréguiberry*, the *Masséna*, the *Bouvines*, the *Valmy*, the *D'Assas*, the *Foudre*, and the *Casabianca* have been

fitted with D'Allest boilers, but it has been proved that they require such care in working that they are no longer being put into French warships.

2. *Slightly Elastic Constructions.*—Those boilers also in which either one or both water chambers can move, and so follow the expansion of the tubes, also logically appear to be excluded if straight tubes are placed between the two chambers. The tubes which are nearest to the fire—either the lowest rows, or, if the arrangement is vertical, the inner rows—will become hotter than the upper, or outer rows; and even among the tubes which are equally close to the furnace, some few will at times be hotter, from the state of the fires, than others, some of which may again possibly be abnormally cooled for the moment by the cold air entering when coal is put on; as a consequence, the length of the tubes will vary, and this must cause a stress on the tube joints in the tube plates, because any tube which becomes shorter through cooling has a tendency to draw away from the tube plates, whilst a tube becoming longer by expansion tends to thrust itself into the plate. This to-and-fro stress on the plate causes the joints to work loose, and, as a consequence, under higher forcing and inefficient stoking, heavy leakages suddenly develop in the tube plate. For this reason, in choosing the type of boiler the Oriolle, the Watt, the Babcock & Wilcox, and the Yarrow also fell out of the running.

The fact that some of these boilers—just as in the case of the *D'Allest* boiler—have been and are still being fitted in war ships, proves nothing as regards the correctness of their design. Under normal conditions, with moderate forcing and proper treatment, all these boilers remain efficient. On board ships of war, however, account has also to be taken of indifferent or bad treatment; under such conditions the tubes of the Yarrow boilers on board English torpedo boats, as well as on board the Austrian torpedo boat *Viper*, have become bent, so that now so-called "distance pieces" have had to be fitted between the tubes to keep them straight. If such occurrences must be reckoned with, and such expedients have to be adopted because the construction of the water-tube boiler is too rigid to admit of sufficient

play to individual tubes, then it would seem that all boilers liable to a similiar defect are hardly to be recommended for ships of war.

3. *Absolutely Inaccessible Boilers.*—Finally, all water-tube boilers whose tubes are absolutely inaccessible for cleaning, had to be excluded as being quite unsuited to replace cylindrical and locomotive boilers in the Navy; this disposed of such constructions as those of Perkins, Herreshoff, Palmer, Ward (1885 and 1888), Du Temple (1886), Hohenstein and Bellis (1888). These boilers have been little used in war ships, and therefore claim no historical interest in this brief account.

4. *Types Meriting Consideration.*—After what has been said, the only kind of water-tube boilers remaining for consideration were either those in which the tubes are curved in the first instance, and which are not prevented from bending still more under expansion, without thereby causing a stress on their joints in the tube plates; or such boilers as only have their tubes fixed at one end in a water chamber, whilst the other end is free and admits of the tube expanding as necessary. If such a boiler should also have fairly large water and steam chambers, so as to obtain the advantages referred to at II, 1 and 4 without the disadvantages referred to at III, 1 and 2 becoming too prominent, then such a boiler could be profitably used in the Navy, because it would be able to withstand high forcing without becoming leaky, and it would also bid fair, so far as leaking is concerned, to remain uninjured even if the stoking is poor.

The choice thus became restricted to the Reed, Normand, the Thornycroft, and the Schulz among small-tube water-tube boilers, and amongst large-tube boilers to those of Niclausse and Dürr. The last named could only be installed in a fore-and-aft direction, owing to the necessity for their tubes to be inclined horizontally, in order to let the steam generated in them get away freely.

V.—FITTING OF GERMAN WAR SHIPS WITH WATER-TUBE BOILERS.

1. *Fitting of Ships with Thornycroft, Schulz and Dürr Boilers.*—Of the boilers open to choice, those with small tubes were

the lightest but difficult to inspect, whilst those with large tubes were easy to inspect, but complicated owing to the large number of doors. It was not easy to foresee which of these drawbacks would prove to be the most prejudicial on board ship, and the only course open was to build boilers of both types, and to fit up some ships with one and others with the other type, leaving the final decision as to the type of boiler to be eventually selected for general use in the Navy to depend upon the results obtained after the various systems had been thoroughly and practically tested. To fit up an experimental ship with various kinds of water-tube boilers was not admissible because, on the one hand, any conclusions so arrived at as to the suitableness of a given boiler for use on board ship would have been still open to question, whilst, on the other hand, the introduction of water-tube boilers could no longer be deferred if we were to compete with other countries, all of which had already adopted them, and thereby obtained increased speed in their ships together with a diminution in the weight of machinery. Nor, finally, could the construction of boilers for the new ships be postponed pending the result of the steam trials of the ships first fitted with water-tube boilers; hence it has come about that during the last six years a number of ships have been fitted with boilers of both kinds, small tube and large tube, without, up to the present, any definite conclusions having been arrived at as to the selection of the future type of water-tube boiler.

The trials in 1893 of the Thornycroft boilers fitted on board the English torpedo-gunboat *Speedy* had already favorably drawn the attention of the German Admiralty authorities towards small-tube boilers. Amongst the types of foreign design belonging to this class available for selection—the Reed, Normand and Thornycroft—the last-named was preferred, but an order was at the same time given for a Schulz boiler, because this latter seemed to promise certain advantages over the Thornycroft which had already been tried.

As regards large-tube water-tube boilers these were first tried in 1895 on board the mining ship *Rhein*, for which the Dürr firm at Düsseldorf had constructed a boiler. The results obtained

from this boiler were certainly hardly satisfactory; its efficiency proved to be no greater than a cylindrical boiler, it gave wet steam and was inaccessible for cleaning of the fire surfaces. On the other hand, steam trials which were carried out at Düsseldorf, in the summer of 1896, with a new and improved Dürr boiler gave such good results in every respect that it became possible to proceed with the construction of such boilers for use in war ships.

The following water-tube boilers have thus been ordered for the German Navy during the last few years:

In 1894—

1. Thornycroft boilers for H.I.M.S. *Ægir*, and for torpedo boat *S 74*.
2. Schulz boilers for torpedo boat *S 42*.

In 1896—

1. Thornycroft boilers for torpedo boats *S 82* to *S 87*, and for divisional torpedo boat *D 10*.
2. Thornycroft boilers in conjunction with cylindrical boilers for H.I.M.S. *Kaiser Friedrich III.*
3. Schulz boilers for torpedo boats *G 88* and *S 89*.
4. Dürr boilers for H.I.M.S. *Baden*.

In 1897—

1. Thornycroft boilers for the gunboat *Iltis*.
2. Schulz boilers for H.I.M.S. *Württemberg*.
3. Dürr boilers for H.I.M. ships *Bayern* and *Vineta*.

In 1898—

1. Thornycroft boilers for the gunboats *Jaguar*, *Tiger* and *Luchs*, for the small cruiser *Niobe*, for the armored coast-defense ships *Hagen* and *Beowulf*, and for torpedo boats *S 90* to *S 101*.
2. Schulz boilers for the small cruiser *Nymphe*.
3. Schulz boilers in conjunction with cylindrical boilers for H.I.M. ships *Fürst Bismarck*, *Kaiser Wilhelm II*, and *Kaiser Karl der Grosse*.
4. Dürr boilers for the large cruiser *Victoria Luise*, and for the armored ship *Sachsen*.

In 1899—

1. Thornycroft boilers in conjunction with cylindrical boilers for the battle ship *Barbarossa.*
2. Schulz boilers for the small cruisers *Thetis, Ariadne, Medusa* and *Amazone,* and for torpedo boats *S 15, S 16* and *S 37.*
3. Schulz boilers in conjunction with cylindrical boilers for the battle ships *Kaiser Wilhelm der Grosse, Wittelsbach* and *E.*

1900—

1. Thornycroft boilers in conjunction with cylindrical boilers for the battle ship *D.*
2. Schulz boilers for gun boat *A,* and for the armored coast-defense ships *Heimdall* and *Hildebrand.*
3. Schulz boilers in conjunction with cylindrical boilers for the battle ships *F* and *G.*
4. Dürr boilers for the large cruisers *Prinz Heinrich* and *B.*

On the one hand, it will thus be seen that the Thornycroft boilers are being gradually pushed aside by the Schulz boilers; and, on the other, that up to the present no decision has yet been come to fit the large battle ships with only water-tube boilers, but a mixed system of cylindrical and of small-tube water-tube boilers has been chosen for them. By this selection the boiler installations have been kept as light as when only cylindrical boilers were used, and yet, while account has been taken to some extent of the prejudice against water-tube boilers from their difficulty of management and their sensitiveness, the good points of both systems have been united in one and the same ship. To meet the case of defective condensers and impure feed water there are the relatively less susceptible cylindrical boilers, and to meet the need for raising steam quickly and forced draft there are the relatively less susceptible water-tube boilers. Water-tube boilers had at first, and still have, the reputation of burning more coal for the same power than cylindrical boilers, especially if running continuously over long distances. The large battle ships, in which the need for saving weight was not of so pressing

a nature as in the large cruisers and gunboats, with their combination of boilers, will consequently be enabled, when steaming at "ordinary" speed on long runs, to use the more economical cylindrical boilers.

If in course of time water-tube boilers should prove themselves to be as economical as cylindrical boilers, and also as entirely safe to use, if by any chance it might become necessary to feed them for some days with brackish water, there will no longer be any impediment to fitting large battle ships exclusively with water-tube boilers, and it will be possible in this class of ship also to effect an important saving of weight.

The Belleville Boiler.—The design of the Belleville boiler does not comply with the requirements which have been laid down here at IV, 4. In this type of water-tube boilers the large tubes have one end attached to a steam collector, the other ends, however, are not arranged free but open out into small water chambers which receive the feed-water, and for this purpose are attached to a common tube. The tubes rest with the lowest back row of their junction boxes on the boiler supports by means of rollers which in a measure form movable feet to the boiler. The water tubes themselves consist of straight tubes screwed into junction boxes and arranged in zig-zag order. There is thus the possibility of an expansion of the tubes if the cylindrical steam collector is somewhat lifted from the tube system. The circulation, moreover, necessitates having an exceptionally low level of water, the water capacity is therefore very small and the disadvantages in connection with water-tube boilers, referred to at III, 1, are especially marked in this boiler. Besides, this boiler could not be forced to any extent, and it had to be worked at a very high steam pressure, which was reduced in the pipes on its way to the engines by some five atmospheres, as otherwise the steam produced was hardly sufficiently dry.

The following ships are, or were, fitted with Belleville boilers:

In England: *Sharpshooter, Powerful, Terrible, Diadem, Arrogant, Furious, Gladiator, Andromeda, Europa, Niobe, Vindictive, Amphitrite, Argonaut, Ariadne, Spartiate, Hermes, Highflyer* and *Hyacinth.*

In France: *Isly*, *Descartes*, *Pothuau*, *Charlemagne*, *Pascal*, *Bouvet*, *Gaulois*, *Saint-Louis* and *Galilée*.

2. Trial of Niclausse and Belleville Boilers.—As will be seen from the foregoing list, speaking generally, two systems of water-tube boilers are in use in the German Navy: First, the Thornycroft and the improved Thornycroft—the latter being represented by the Schulz, and, second, the Dürr boilers. The fact that the other great naval powers showed a preference for other types caused the German naval authorities to experimentally fit up a few ships with these other types in order to be able to compare them with those which the German constructors considered to be the best kinds of boilers. As a consequence the Schiff-und Maschinenbau-Aktien Gesellschaft Germania were ordered in the winter 1895–6 to supply H. I. M. large cruiser *Freya* with Niclausse boilers, and Belleville boilers for the large cruiser *Hertha* were ordered from the Stettiner Maschinenbau-Aktien Gesellschaft Vulcan. About a year later Niclausse boilers were ordered for the small cruiser *Gazelle*, and Belleville boilers for the large cruiser *Hansa*.

In principle the design of the Niclausse boiler is similar to that of the Dürr boiler, but it differs considerably from the latter in matters of detail, and that, as will be seen later, not to its advantage. At that time, according to reports appearing in the French newspapers, such good results had been obtained from Niclausse boilers on board the protected cruiser *Friant* in France, and in England on board the torpedo gunboat *Seagull*, that the French Admiralty decided to equip quite a number of large ships with these boilers.

The following are the names of the French warships which either have been, or which still are, provided with Niclausse boilers: *Suffren*, *Marceau*, *Henri IV*, *Condé*, *Gueydon*, *Kléber*, *Requin*, *Friant*, *Fleurus*, *Téméraire*, *Zélée* and *Décidée*.

3. Trial of Yarrow and Normand Boilers.—In order to leave nothing uninvestigated, the German Admiralty in 1896 and in 1899 gave orders for torpedo boat *S 32* to be fitted with Yarrow boilers and for divisional torpedo boat *D 3* to be fitted with Normand boilers.

VI.—EXPERIENCES WITH WATER-TUBE BOILERS.

1. With Small-Tube Boilers.—The trials of the Thornycroft boilers on board H. I. M. S. *Ægir*, and on board torpedo boats *S 82* to *S 87*, and also of the Schulz boilers in torpedo boats *S 42*, *G 88* and *G 89*, were on the whole satisfactory, and especially demonstrated the superiority of this boiler over the locomotive boilers with which the ships of the *Ægir* class and the torpedo boats had hitherto been fitted, in so far that the boilers remained in good condition under any kind of forcing and treatment of the fires. The fear that the small tubes, when impure water was used, would become obstructed and then get red hot and burst was, however, justified. As a water tube in a Dürr boiler on board H. I. M. S. *Baden* also got foul with scale and grease, thereby causing it to get red hot at a weak place and burst, orders were issued that all water-tube boilers should be filled and fed with distilled water only, and other measures were adopted to prevent the accumulation of harmful greasy deposits on the inner surfaces of the tubes. The evaporators for all ships fitted with water-tube boilers were made of such dimensions that, under any circumstances, distilled water only could be used for boiler "make-up" feed; feed-water filters were also inserted in the delivery pipes of the air pumps, and into the delivery pipes of the feed pumps, and measures were likewise taken to keep soda constantly mixed with the feed water. Since the introduction of these expedients no bursting of tubes has taken place either in the small-tube water-tube boilers or in the Dürr boilers.

The fact that the small water chambers serve as bottom-tube plates to the outer rows of tubes at first greatly impeded the cleaning of the insides of the tubes of the *Daring* type of Thornycroft boilers; in the original Thornycroft boilers fitted on board divisional torpedo-boat *D 10* their internal diameter was only 6 inches; the diameter of these water chambers has lately been increased to between 15 and 17¾ inches, so that they can now be easily examined.

The cleaning of the insides of the small water tubes was further greatly impeded by the ends of the tubes being tapered to a less diameter than the body of the tubes, in order not to weaken

the tubes' plates too much and to enable the tubes to lie closer. This is now no longer the case, and the following method of cleaning has accordingly been laid down. As a rule, a frequent scouring of the boiler with soda and blowing out the soda solution, which carries with it the loosened grease and dirt, is sufficient; after which the tubes are washed out from the steam collector with water under pressure. Once every year, however, the same special inspection and thorough inner cleaning as is prescribed for cylindrical and locomotive boilers is to be undertaken. The cleaning instruments consist of small steel brushes and scrapers made of watch springs, which are drawn through the tubes by steel-wire cords—using for the purpose a friction roller arrangement—and so scrape off the deposits adhering to the inner walls of the tubes. This cleaning is carried out by one petty officer and five stokers in 200 hours, that is to say 20 days of 10 working hours, and is sufficient, so far as the experience hitherto obtained with forced draft in torpedo boats goes to show, to prevent any irregularities in the working of the boilers. Less thorough cleanings have been carried out on board the *Württemberg*, after 700 hours' steaming, in 8 days.

On board the gunboats *Iltis* and *Jaguar* also—the *Iltis* has already been in commission for more than two years, and for most of the time under unfavorable conditions—irregularities in working have only been reported in a single case, where it was clearly shown that the cause was attributable to want of water; in this case in the boiler concerned the joints of the tubes in the steam collector tube plates leaked.

One defect noted in the Thornycroft boilers on board torpedo boats *S 82* to *S 87* was attributable to the short distance which the hot gases pass over among the tube nests on the way from the grate to the uptake. Under forced draft the flames shoot up above the short funnels, and the boats consequently are visible at long distances by night. If the funnels are raised, the flames no longer issue from them, but the uptakes become so heated that economical working cannot be expected. In the Schulz boilers, which are really in essentials improved Thornycroft and Normand boilers, this inconvenience is obviated by arranging

the tubes in single rows, and so making them to serve as guide walls to the hot gases, which are thus made to travel such a long distance among the tube nests, that they give up sufficient heat to the water as to prevent the formation of flames in the funnels, whilst also insuring good utilization of the gases. As regards coal consumption, when traveling at a speed of 12 knots, the consumption on board the torpedo boat *S 83* was 2.2 pounds, and on board divisional torpedo boat *D 10*, 2.64 pounds per I.H.P. per hour, both being fitted with Thornycroft boilers; on the other hand, the consumption on board *G 88*, which is fitted with Schulz boilers, was only 1.59 pounds, or just 28 per cent. less than the amount of coal consumed on the similar sized torpedo boat *S 83*; the heat registered in the funnels of the Thornycroft boilers was 700 degrees centigrade (1,292 degrees Fahrenheit) as against from 412 degrees to 425 degrees centigrade (773 degrees to 797 degrees Fahrenheit) in the funnels of the Schulz boilers.

The Thornycroft, and also the first Schulz boilers, had the disadvantage that when preserved full of water, which is generally advisable when the boats are being kept ready for service, all the air could not be expelled from the upper bends of the water tubes. In the Thornycroft boilers, where the tubes discharge above the water level in the steam collector, this inconvenience cannot be remedied; the Schulz boilers, however, are now so constructed that the highest part of the upper bends in the tubes do not lie higher than the openings into the steam collector, and this arrangement consequently obviates the inconvenience in question.

The fear at one time expressed, that the water circulation in the tubes when working at a moderate rate would be so small that some of the tubes would become red hot and burn through, has hitherto proved groundless. The tubes put into the Thornycroft boilers of H. I. M. S. *Ægir* four years ago, even the top ones, lying nearest the steam collector, have their ends, which are expanded in the tube plate, still in good condition. These ends are, however, rusted inside, and this must be attributed principally to the galvanic action arising from the brass baffle

plates originally fitted, and from the bronze feed regulators arranged inside the steam collectors with the copper feed and steam pipes. The harmful effects of galvanic action on the steam collector and generating tubes will, in future, be obviated by making these fittings of iron and steel.

At first, the tubes in the boilers of torpedo boats *S 74* and *S 82* to *S 87* suffered rapid deterioration from the outside, but since greater attention has been paid to keeping the ends of the tubes dry, especially the lower ones lying next to the water chambers, which become covered with dirt, the tubes have remained sound. On board the *Ægir*, the zincing on the outside of the tubes has worn off completely after four years' service, but the thickness of the tubes has not perceptibly diminished. These tubes in the Thornycroft boilers of the *Ægir*, in consequence of this diminution in the strength of the upper short ends, are now to be renewed; as, however, the tubes are otherwise sound, the long tubes are to have their ends cut, and after re-zincing will be replaced and again used as shorter tubes, so that out of 3,300 tubes only 900 require to be replaced. This repair is necessary in order to insure the boiler working reliably for some years, but in the event of war the tubes could have been left in the boiler in their present condition without any danger.

If the same experience obtains as to the life of the tubes in the latest Schulz boilers, it may be assumed that these boilers will require re-tubing every four years; it is, however probable that by utilizing the experience acquired in the meantime, the lives of these boilers will be considerably prolonged. In any case, it should not be overlooked that the tubes in cylindrical and locomotive boilers require to be renewed after about five years' wear.

Speaking roughly, the probable serviceableness of the latest Schulz boilers should not be judged from the experience gained with the first, and in many respects imperfect boilers of this and of the original Thornycroft types. In any case, however, the duration of life of the improved Schulz boilers is as yet unknown, and the distrust of the opponents of small-tube boilers to the durability of the tubes in this boiler is explicable if they reckon on having to meet the enemy with ships whose tubes are from four

to five years old. The thickness of these tubes, as with all water and fire tubes, can only be ascertained by taking out and cutting up certain specimen tubes. This test is applied once a year, the same as it is to cylindrical and locomotive boilers which have iron tubes, under the instructions for the inspection of boilers already referred to, and so far this inspection has sufficed to prevent the tubes bursting after becoming thin. It must be remembered that the stress on the material of the small water tubes is only from 0.48 to 0.65 kilogramme per square millimeter (682.7 to 924.5 pounds per square inch), which is only about $\frac{1}{60}$th of the ultimate strength of 34 kilogrammes per square millimeter. Any ordinary wasting of the material of the tubes caused by rust and wear can therefore hardly bring about the bursting of a tube. The only things detrimental to the durability of small tubes is the scale developed on their inner surfaces as referred to at III, 3. It would therefore be desirable if a system of inspection could be introduced which would admit of its being possible to ascertain whether the inner surfaces are clean enough to obviate any anxiety being felt in regard to the possibility of the tubes becoming choked when the boilers are worked for prolonged periods. Up to now scale alone has not caused any bursting of small tubes, this having only taken place from a complete stoppage in the tubes; this is easily explained by the fact that even with the reduction of conductivity to heat, the tubes do not become so hot that their diminished strength renders them incapable of withstanding the comparatively small strain thrown upon them; only complete cessation of the water circulation apparently brings about this excessive heating of the tubes. An inspection of the inner heating surfaces of the small tubes in the Thornycroft and Schulz boilers is, however, only possible by passing a steel wire brush through each separate tube, which is obviously an inconvenient and lengthy proceeding; if the brush can pass, then it is clear that there is no great fouling or formation of scale, but beyond this nothing further is conclusively proved. Time alone will show whether the formation of scale on the inner surfaces of the tubes will still continue when using distilled water only for the feed, and the measures now adopted

for filtering the feed water and keeping it alkaline with soda. Up to the present such has not been the case; but account will always have to be taken of the possibility of leaky condensers and consequent brackishness of the boiler water. If, even with leaky condensers, injurious deposits of scale do not take place, then the inspection of the inside of the curved water tubes by viewing can be dispensed with, and the examination of the tubes can be limited to the yearly special survey and to cutting up certain tubes as samples; in such case these boilers could then be considered as quite safe for working. So long, however, as this has not been definitely established, the engineer in charge would do well, if any defect or leak should manifest itself in the condensers to frequently change the boiler water and to clean and refill the boilers not in use. Under such circumstances it would be inadvisable to undertake a long run at high speed with all the boilers working, until the defect in the condensers had been remedied.

The opponents of small-tube water-tube boilers specially put forward the assertion that the captain cannot be responsible for the engineers having the boilers clean at any moment, and, consequently, in a state of readiness for war. On this point it is to be observed that locomotive boilers which the engineers in charge had considered to be sufficiently clean became completely unworkable for a considerable time in a trip between Wilhelmshaven and Kiel owing to leakage at the tube plates, which, on a closer inspection of the boiler being made by removing some of the tubes, proved to be due to the ends of the tubes being covered with a thick crust of salt close to the tube plates. This incident occurred some five years ago on board H. I. M. S. *Beowulf*. The case, however, in which cylindrical boilers became unworkable because of their tubes becoming encrusted with salt, or scale, are not infrequent. It may be conceded that cylindrical boilers do not become dangerously oversalted as quickly as water-tube boilers.

The cleaning of the exterior of water-tubes is carried out by means of compressed air from the air blowers, and is no longer attended with difficulties.

2. *With Dürr Boilers.*—The experience with Dürr boilers has also proved so far successful that the boilers have shown themselves to be unaffected by heavy forcing and to sudden changes in the draft. The solitary case of a tube bursting through extensive fouling has already been mentioned at VI, 1. Dürr boilers are heavier than small-tube water-tube boilers, but they possess an advantage over the latter type in the ease with which the cleanliness of the inner surfaces of the tubes can be ascertained. It is true, however, that in respect of this inspection, if it is to extend to all the tubes, an enormous number of doors, one at least for each tube, have to be opened out and closed again, which necessarily takes up much time and labor, more especially so, as the inner tube of each generating tube has to be taken out and replaced. Practical experience has, however, shown that it is principally the lowest tubes which foul, and as a rule, therefore, it is only necessary to examine the three lowest rows of tubes, and if these are found to be clean the upper rows need not be examined. But in order to carry out a thorough cleaning of the boiler the whole of the tube-hole doors, both at the front and back, must be opened, and this means for a ship like the large cruiser *Prinz Heinrich*, which has 14 boilers with 574 water tubes in each, the removal of $2 \times 14 \times 574 = 16{,}072$ doors. An extensive cleaning of the boilers takes place after each steaming period of from 700 to 1,000 hours. On such occasions all the tube-hole doors are opened and each outer tube is scraped and washed. All the inner tubes are also swept with steel brushes and washed out inside. Such a cleaning, necessitating the opening up, cleaning and closing again of the boiler, takes up the time of two petty officers and ten stokers for 38 hours for each boiler, which makes four days of ten working hours for each.

The original construction of the back-tube stoppers, which is very solid and absolutely safe, greatly hindered the work of cleaning, because the inner conical plug had to be pulled out to the front of the boiler, and after the tube was cleaned the plug had to be pushed in again to the back end of the tube. Recently, however, the back closing arrangement has taken the form of a cap nut. This closing arrangement having been experimentally

tried on some of the tubes in the *Victoria Luise* and *Sachsen*, and having been found to answer, the tubes in the Dürr boilers of the *Prinz Heinrich* and of the large cruiser *B* are closed with the new cap nuts. The time required for cleaning the boilers will be materially shortened by this improvement. These cap nuts are made of wrought bronze of great strength, and have V section ridges turned on the face for making the joint instead of the conical threads used with the cap nuts of Niclausse boilers.

In the later Dürr boilers the water chambers extend farther below the lowest row of tubes and form a sediment chamber; it may be assumed, therefore, that the tubes will in future be cleaner, and that the intervals between the thorough cleanings of the boilers will be longer. Presumably also, ships, even on foreign service, fitted with the latter boilers, will only need to have their boilers thoroughly cleaned twice a year, provided that the condensers do not leak; as bearing upon this the condensers will in future, perhaps, prove more reliable now that their tubes are to be made of stronger material. If the condensers are leaky and the boiler water becomes brackish in consequence, the boilers prime heavily, especially if the water at the same time contains soda. However, these boilers have not proved themselves to be so greatly affected by being fed with brackish water as was feared by many persons. On board the *Sachsen* a Dürr boiler was at work continuously on harbor service for some days with feed water containing 10 per cent. of salt without any of the tubes becoming heated. Salt scale, especially at the back ends of the lowest water tubes, 2 millimeters (.079 inch) thick, which has been formed in this way, has had no injurious effect. The stress on the material is also relatively small in the tubes of these boilers, and the margin of safety is high.

Great care must be taken in preserving the inner tubes, which are made of quite thin mild-steel plates, and the superheater tubes. The boilers should either be preserved by the wet method, *i. e.*, by keeping them quite full of water, or by the dry method, when they are not in use. If by chance the boiler water is blown out through the blow-off cock, and the tubes are not at the same time emptied—as happened when the *Victoria Luise* was first

put out of commission—the upper ends of the inner tubes are deprived of water, and being surrounded with damp air quickly rust. At first the tubes used to be emptied by syphoning from the front; but lately the practice on board the *Sachsen* has been to loosen the back conical tube stopper. The new style of closing by means of cap nuts will still further facilitate emptying the tubes. In the opinion of the captain of the *Sachsen* the introduction of this closing arrangement will enable a complete change of water to be affected in a Dürr boiler in from three to four hours. The thin tubes in the superheater, similarly to the inner tubes, are liable to be injuriously affected by damp or air unless the boiler after ceasing to work, is either kept quite full or quite dry. Hitherto the system of design made it difficult to completely fill the superheater tubes; but in the boilers now being built this inconvenience is being remedied by providing means of exhausting the air from them.

The back walls of the Dürr boilers necessitated constant repairs. The tubes which are fixed in the tube plates of the water chamber by thickened and skewed cones lie with their back ends free in a latticed wall, the openings in which serve at the same time to help the cleaning of the tubes, which is carried out by means of forced draft from the boiler room. These openings are closed with plates lined with asbestos pulp, which are fastened to the lattice work by pins and cottars. These plates, however, become warped and often burnt by the heat, so that labor is entailed in straightening or replacing them. The side wall casings, as in all water-tube boilers, also suffer from the heat, because the outer rows of tubes, which form the external wall of the furnace, can never be kept quite tight, and yet all these casing plates have to be as thin as possible to keep down the weight of the boiler. The cleaning of the fire side of the outer tubes, which at first occasioned trouble, can now be carried out in a simple manner, even whilst the boiler is working, by forcing air, under pressure, through from the ventilating fans, with the ash-pit doors closed and the furnace doors open. The air passing over the fire into the furnace blows most of the soot which is lying on the tubes out through the funnels. This soot

has been the principal cause of the economy of the Dürr boilers having hitherto, when running for long distances, been less apparent than it was on the official acceptance trials. It may, however, be taken for granted that this inconvenience will not in future make itself felt to the same extent if the furnaces, when making long runs, have air blown through them. When a thorough cleaning is to be made, with the boilers cold, the air, as already remarked, will be blown through the lattice-work into the tube nests, the back-casing plates being removed singly for the purpose as necessary. With a view to more effectually removing the soot which collects on the baffle plates used for directing the course of the gases, a shaking arrangement has lately been fitted to the baffles. The Dürr boilers have thus either been, or are being, improved as a result of the experience gained from their working on board ship. At first the consensus of opinion was undoubtedly against these boilers, because so much work was occasioned in the handling and keeping in order of the numerous doors, and because of the constant exertion entailed upon the boiler-room *personnel.* These boilers, however, should not be judged by the experience of the first types alone, but judgment on them should be suspended until experience has been obtained with the later types. It may be said, however, that even the present opponents of this system appreciate its advantages in regard to facility of inspection, and do not counsel its abandonment. It has recently been decided to build more of these boilers, and that the large cruiser about to be constructed to replace the *König Wilhelm* should be fitted with Dürr boilers.

3. *With Niclausse Boilers.*—The experience of the German Navy with Niclausse boilers has so far been very unsatisfactory. In October, 1898, the small cruiser *Gazelle* and the large cruiser *Freya,* both of which are fitted with Niclausse boilers, made their first trial trips, and it was not until April, 1901, that the *Gazelle* could be commissioned with serviceable boilers, and that the *Freya* could continue her interrupted trials. The interval was taken up in making repeated alterations in the boilers.

The most serious defect in this boiler is attributable to the

large use made of malleable cast iron, a material which should be altogether excluded in boiler construction. This material is cast-iron, to which greater strength than is possessed by ordinary cast iron is imparted by heating it without air in a layer of coal dust. The resulting material is not so brittle as cast iron, but is not equal in tenacity to wrought iron, and in consequence of the strains set up in cooling after the casting, easily bursts.

Immediately after the first trials cracks were noticed in the malleable cast-iron headers and lanterns. The cracks in the headers, which were in the diaphragm and extended from one tube hole to another, were not dangerous; those which ran in the direction of the outer walls could for the most part be drilled and made harmless, so that the water chambers could, at least for a time, be considered as safe to work. The lanterns, however, were all replaced by others made of mild steel, because the complete fracture of both webs of a lantern would be followed by the breaking off of the dog of the tube-hole door—at that time still made of malleable cast iron—which would have dangerously imperilled the lives of the stokers in the boiler room.

The long drawn-out negotiations between the Admiralty and the contractors for the engines, the Schiff- und Maschinenbau-Aktien-Gesellschaft Germania, and between this latter company and the patentees of the boiler, the Niclausse firm in Paris, as well as the preparation of a large number of new lanterns and fitting them in the boilers, took a very long time; finally, however, when after an interval of two years the *Freya* was able to recommence her trials, one of the outer tubes burst, and the back cap nut of another outer tube stripped off. On inspecting the boiler a large number of tubes were found to be considerably bent upwards, and, from the appearance of the tubes, it was evident that they had been red hot. The only reason for the tubes getting red hot must have been from want of water, but as the gauge glasses during the run indicated a sufficiency of water the deficiency in the tubes must have been due to defective circulation. This view was borne out by the fact that during the trial run the ship was considerably out of trim and that the greatest bending in the tubes and the bursts which occurred in two sep-

arate boilers took place in those boilers where tubes had assumed a more horizontal position than their customary angle of inclination owing to the ship's want of trim.

On examining the front part of the headers it was seen that in some cases the ports in the lanterns between the webs and through the holders of the inner tubes were somewhat small, and in others that the lanterns had too great an amount of play in the diaphragm plate in the headers, so that a portion of the water entered the back part of the headers without passing through the inner tubes. The construction of the lanterns did not admit of a further weakening of the webs; it was to be assumed, however, that the ports in the lanterns would be large enough if the lanterns were arranged in the headers in such a way that ports in the lantern and the holder for the inner tube were turned so as to lie up and down, and if the play in the diaphragm were reduced to a minimum by a thickening of the lantern at this point. From a trial made during a six hours' run with a boiler altered in this way in H. I. M. S. *Freya*, with the ship properly trimmed and with forced fires, *i. e.*, with a consumption of 170 kilogrammes of coal per square meter (34.8 pounds per square foot) of grate area per hour, this surmise was proved to be correct, and the whole of the boilers in the *Freya* and *Gazelle* were altered accordingly. The tubes in the Niclausse boilers have an inclination of 6 degrees to the horizontal; in the trial run on board the *Freya*, when the accident took place, this inclination was diminished to about 5 degrees. At the time of the accident the webs for the most part were arranged up and down and the holders for the inner tubes lay below and so covered the lower ports underneath. With this arrangement the circulation of the water proved sufficient even under unfavorable trimming of the ship. As was shown by the experiments carried out by Professor Gutermuth with the Dürr boiler, the circulation of water, when the tubes have as small an inclination as only 1 degree to the horizontal, is sufficient to prevent the tubes from getting red hot. Moreover, it should be borne in mind that the flow of water from the water chamber into the inner tubes is much less impeded in the Dürr boiler than in the Niclausse boiler. It goes without say-

ing that it is an essential requirement in ships' boilers that they should be able to stand changes in the trim of the ship without ill effects.

Similar accidents to the one which occurred on board the *Freya* have also taken place in the Italian armored cruiser *Garibaldi*, which is fitted with Niclausse boilers. The French press have not allowed any accidents to Niclausse boilers to become known; it may, however, be surmised that such must also have occurred on board French war ships, since Niclausse has given up the less reliable, but cheaper, malleable cast iron, and now fits his boilers exclusively with the much more expensive mild steel (*flusseisen*).

It should further be mentioned that in some pressure trials of water tubes, carried out after the substitution of mild-steel lanterns for the malleable cast-iron lanterns, a large number of the cap nuts, also made out of malleable cast iron, used for closing the back ends of the tubes, burst; it is probable that they were screwed up on the conical threads with too much force. In consequence of this experience all the cap nuts were replaced with others of mild steel.

Even after making these alterations, the design of the Niclausse boilers still gives rise to a certain amount of danger in so far that some amount of stress is present which tends to lift the tubes from their seatings in the headers and to force them out of the headers towards the firing space. Under normal conditions this stress is taken up by the friction in the conical seatings and by the dogs on the front walls of the water chambers, each of which holds two tube doors, and which are secured to the malleable cast-iron headers by means of studs and nuts. If at any time, however, any of the tubes show signs of leakage, it is very convenient for the stokers to screw down the nuts on the studs of the dogs and thereby to put a stress on the tubes, which may easily cause a stud to draw out of the thread in the malleable cast iron; if this occurs, then the two tubes concerned are only retained in the boiler by the friction in the conical seatings. In the Dürr boiler the tubes are forced against the conical seatings by the pressure of the water, and the hand-hole doors in the front

tube plate are absolutely secure from any danger of flying out because the openings in the tube plates into which they bed are coned, with the large end inside.

This element of safety serves, to some extent, as a set-off to the difficulty experienced in removing and replacing the hand-hole doors.

How the fine-cut threads are likely to last time alone will show. In Germany, such threads have hitherto only been used in telescope making, but never in boiler construction. On board H. I. M. S. *Gazelle*, where some of the fittings of the blow-off cocks on the front of the water chambers are screwed with similar fine threads, they have hitherto leaked continually.

The attachment of the headers to the steam collector also can hardly be considered as being solid; some of the studs broke off, even when the boilers were being erected.

After these experiences and after a critical examination of the details of design, there is no reason why we should exchange the proved solid construction of the Dürr boiler for that of the Niclausse boiler, especially when all that has been adduced against the Dürr boiler at VI, 2, is also to be met with in the Niclausse boiler, and when the details of design in which the Niclausse boilers differ from the Dürr boilers compare unfavorably with similiar details in the Dürr boiler.

4. *With Belleville Boilers.*—The Belleville boilers without economizers, as fitted on board H. I. M. ships *Hertha* and *Hansa*, have the reputation of being very uneconomical, and it is partly for this reason that this type of boiler is being given up in England. The coal consumption in the acceptance trials of the *Hertha* and *Hansa* was, on the average, 1.98 pounds per I.H.P. both for the continuous full-power trials and for the ordinary speed trials, and consequently does not compare unfavorably with many of the runs made with cylindrical and locomotive boilers, or with other types of water tube boilers; especially considering the moderate forcing of the boilers with a coal consumption of from 16.69 pounds to 17.56 pounds per square foot of grate area per hour for the full-power trials, and of from 8.35 pounds to 8.6 pounds for the ordinary speed trials.

When H. I. M. S. *Hertha* went out to the China station the mean coal consumption of ten continuous hours at ordinary speed was 13.5 pounds per square foot of grate surface per hour, which is equal to a consumption of 2.9 pounds per I.H.P. per hour; on some runs, with 4,600 I.H.P., the consumption was 2.8 pounds per I.H.P. On the other hand, from a report sent in by the captain of the *Hertha*, it appears that on a previous occasion, after the boilers had been thoroughly cleaned and the engines had been overhauled, during a 24-hours run at ordinary speed and with a coal consumption per hour of 11.67 pounds per square foot of grate surface, the consumption per I.H.P. was only 1.79 pounds per hour. According to the newspapers the English cruiser *Europa* was said to have consumed during her contractors' trials, when her boilers were new and clean, only 1.54 pounds of coal per I.H.P. per hour, whereas later, when going at ordinary speed, the consumption rose to 4.85 pounds per I.H.P. It appears, therefore, as if these boilers foul very much when working continuously, and, consequently become uneconomical.

During the construction of the boilers for the *Hertha* and *Hansa* much stress was laid by the makers in having Serve tubes for the lowest rows, which are those most exposed to the fire. Such tubes, however, at that time could only be made by welding, and three of them burst at the welds when the boilers were being worked. Even with only three burst tubes out of a total of 792 welded tubes—barely 0.4 per cent.—the possibility of further bursts taking place, entailing probable injury to the stokers, was considered too serious a risk to be incurred, hence the whole of the Serve tubes have now been replaced by ordinary seamless tubes. Although the effect of this alteration was to diminish the steaming efficiency of the boilers, it increased the safety of working.

Similiar unfortunate experiences attended the working of Belleville boilers in the English Navy. Here also the welded Serve tubes have been replaced by seamless tubes.

Allusion has already been made at V, 2, to the disadvantage possessed by these boilers as compared with other water-tube

boilers by reason of their unusually small water capacity, and the consequent introduction of reducing valves in the steam pipes. These reducing valves have often given rise to trouble when steaming. Moreover, the use of high-pressure steam necessitates comparatively great strength in the materials of the steam pipes, and consequently requires heavy pipes because the reducing valves are not reliable, and the strength of the pipes even beyond the reducing valves require to be calculated for the higher steam pressure.

Above all, however, these boilers have been found to suffer considerably if used with leaky condensers. In spite of their being only fed with distilled water, thick deposits of salt have frequently been found to take place as the result of any defect in the condensers. These deposits especially occur in the upper tubes, which at times become almost completely chocked. In order to prevent explosions from taking place from this cause, Belleville places small fusible plugs of lead in the junction boxes, which melt as soon as the tubes become hot through any obstruction of the circulation. The hissing of the steam issuing from the small holes thus made in the boxes warns the stokers of the coming danger; thereupon the fires are drawn and the boiler, after becoming cool, is examined and cleaned. Such occurrences often took place on board the *Hertha* and *Hansa*, and it is solely owing to the extraordinary care and vigilance of the engine-room complements of these ships that, beyond the bursting of the Serve tubes already referred to, more serious accidents have hitherto been avoided.

Belleville boilers can be inspected, but only by opening a large number of doors which give rise to leakages and repairs. Complaints, as a consequence, are often heard of the great amount of trouble and labor caused to the *personnel* during the process of inspecting, cleaning and repairing these boilers. Their peculiarity of producing wet steam has led to the adoption of a very extensive system of baffle plates, which take up the whole of the steam collector and have to be removed whenever the collector is inspected. These baffle plates suffer considerably by rusting, and also have been quite destroyed by the action of the wet stream

of steam impinging on them. A large number of the plates have already, as a consequence, had to be renewed.

Finally, the shortness of the flame circuit between the tubes has proved very inconvenient. The heated gases enter the uptakes and funnels at a very high temperature and heat them excessively. On board H. I. M. S. *Hertha* the funnels gradually collapsed, necessitating lengthy repairs and the adoption of specially arranged stays before they could be made serviceable again.

Taking everything into account, there are no grounds for again bringing this system of boiler into use in the German Navy.

5. *With Yarrow Boilers.*—I have been unable to obtain any details as to the experience with the two Yarrow boilers fitted on board torpedo boat *S 32*. It has, however, been proved that they are very uneconomical, and as early as 1898, that is to say, after they had only been two years in commission, 145 tubes had to be replaced in each boiler, which necessitated the boilers being taken out of the boat, as otherwise the water chambers were inaccessible. Any further employment of this system of boilers for torpedo boats is considered as inadmissible.

VII.—ECONOMY OF THE VARIOUS SYSTEMS.

It is very difficult to decide on the exact economy of any boiler system. If, in order to ascertain it, experiments are carried out on shore with any individual type its efficiency will be better or worse, entirely according to the skill of the stokers. For instance, recently during some experiments carried out on shore with a Belleville test boiler fired by an ordinary well-trained stoker, such as is generally available, 1 pound of coal converted 7.84 pounds of water at 0 degrees centigrade into steam at 100 degrees centigrade, whereas with a specially skillful stoker, supplied by the makers of the boiler, the quantity of water evaporated was 8.836 pounds; in both cases 35.8 pounds of the same coal were burnt per square foot of grate surface per hour, but in the second experiment the dampers were used at each firing up and the furnace doors were never kept open longer than ten seconds. It is clear that similar results could never be attained on

board ship where a large number of boilers would be simultaneously at work.

Supposing the amount of coal burnt on board ship were to be measured and compared with the I.H.P. developed by the engines, during the period of trial the result would be appreciably influenced by the economy of the engines, by possible leakages from joints and stuffing boxes, and by the not easily ascertainable consumption of the auxiliary engines, especially of the steam-steering engines.

Reliable results could only be obtained by measurements of the feed water; such measurements, however, are very difficult to carry out, because serviceable water meters are not inserted in the feed pipes, and such experiments could therefore seldom be made.

The results obtained on trial runs, apart from those for ascertaining the economy of the boiler, would, to a certain extent, be free from objections if the work done by the boilers was in all cases the same. This, as will be seen from the tabulated results given in Appendix I, is however, never the case.

Even for sister ships which are both fitted with the same types of boiler ordered from different makers, the details of construction which have an effect upon the economy, differ considerably, so that sometimes the differenee in the calorific results between two boiler installations of one and the same system are greater than the difference between installations of quite different systems. A striking instance of this is to be seen in the two Dürr installations on board the *Baden* and *Bayern*.

The coal consumption during the trials of H. I. M. gunboat *Tiger* must be left out of consideration, because the slide-valve packing rings used during these trials have from the experience of the gunboat *Luchs*, built at the same yard, been proved to let steam pass. Besides, when the mean values obtained from the various trial runs with the different systems of boilers are compared, it is found that the difference in the coal consumption per I.H.P. per hour, amounts to about 13 per cent. for ordinary speed and 19 per cent. for continuous full speed.

The following table gives the coal consumption per I.H.P. per hour for the work done by the boiler as stated:

At Ordinary Speed.

Type of boiler.	Coal consumption in pounds per square foot of grate surface per hour.	Coal consumption in pounds per H.P. per hour.
Schulz	16.7	1.96
Niclausse	12.4	1.96
Cylindrical	11.5	2.01
Belleville	8.12	2.01
Dürr	14.0	2.06
Thornycroft	17.5	2.21
Locomotive	14.9	2.23

AT MAXIMUM CONTINUOUS SPEED.

Type of boiler.	Coal consumption in pounds per square foot of grate surface per hour.	Coal consumption in pounds per H.P. per hour.
Thornycroft	23.6	1.79
Niclausse	15.4	1.81
Cylindrical and Schulz	14.0 and 20.7	1.82
Cylindrical and Thornycroft	14.1 and 21.9	1.84
Cylindrical	17.4	1.86
Dürr	19.7	1.91
Locomotive	28.2	1.98
Belleville	17.1	2.01
Schulz	26.9	2.18

Apart from the fact that these two tables show discrepancies in the order of sequence, *e. g.*, the Schulz boilers in the trial runs at ordinary speed occupy the first place, whilst they take nearly the last place in the maximum continuous-speed runs, it will be seen on reference to the tables in Appendix I, that some of the boiler systems have both very low and very high coal consumptions, hence the statement seems justified that the boilers of all these systems, if properly proportioned and properly handled, pretty well all work with the same economy.

This seems to be the case as regards the cylindrical, Schulz, Thornycroft and Dürr boilers, with which the following very

favorable coal consumptions have in certain instances been obtained:

Type of boiler.	On board H. I. M. S.	Pounds per I.H.P per hour.
Cylindrical	*Wörth*,	1.58
Schulz	*Nymphe*,	1.67
Thornycroft	*Iltis*,	1.60
Dürr	*Bayern*,	1.56

As a rule the results of trial runs available are too few for deductions to be drawn from them as to which type of boiler is the best on the score of economy, for it is impossible from two such entirely different results as were given in the ordinary speed trials of the *Württemberg* and *Nymphe*—which vary some 35 per cent. from each other—to take the arithmetical mean, and to use the figure so obtained as a basis from which to judge the economy of the system. It may be taken for granted, however, that the results of the trials so far carried out go to show that equally good results can be obtained from the Schulz and Dürr boilers as from cylindrical boilers.

It was at first freely asserted that water-tube boilers under continuous steaming would be less economical than cylindrical boilers. But this assertion is not borne out by the coal consumed by the First Squadron during a trip to Lisbon in the summer of 1889. In the following table the coal consumption of the ships forming this squadron is given, first for their official acceptance trials, and, secondly, for the voyage referred to at 9 and 12.5 knots speeds:

Name of ship.	Official acceptance trials. lbs. coal per hr.		Voyage to Lisbon. At 9 knots. lbs. coal per hr.		At 12.5 knots. lbs. coal per hr.	
	per sq. foot of grate.	per H.P.	per sq. foot of grate.	per H.P.	per sq. foot of grate.	per H.P.
I.—CYLINDRICAL BOILERS.						
Bradenburg	12.0	1.64	10.9	2.8	16.64	2.205
Weissenburg	12.3	1.74	11	3.13	16.67	2.266
Kurfürst Friedrich Wilhelm	12.9	1.83	9.7	2.8	15.28	2.39
Worth	9.7	1.58	10.3	3.24	14.44	2.081
Mean	*11.7*	*1.70*	*10.46*	*2.998*	*15.76*	*2.237*

Name of ship.	Official acceptance trials. lbs. coal per hr.		Voyage to Lisbon. At 9 knots. lbs. coal per hr.		At 12.5 knots. lbs. coal per hr.	
	per sq. foot of grate.	per H.P.	per sq. foot of grate.	per H.P.	per sq. foot of grate.	per H.P.
2.—Dürr Boilers.						
Baden	15	2.32	18.2	4.056	20.48	2.908
Bayern	14	1.97	15.87	3.064	22.32	2.359
Mean	*14.5*	*2.14*	*17*	*3.56*	*21.4*	*2.632*
3.—Thornycroft Boilers.						
Ægir	10.4	2.15	18.2	3.263	25	2.685

The coal consumption per I.H.P. has, consequently, increased on the average above the acceptance trial consumption as follows:

Type of boiler.	At 9 knots.	At 12.5 knots.
Cylindrical	About 78.7 per cent.	About 33.4 per cent.
Dürr	" 67.5 "	" 24.4 "
Thornycroft	" 53.6 "	" 26.3 "

That is to say, the depreciation in economy, as compared with the official acceptance trials, has been greater with the cylindrical boilers than with the water-tube boilers. If the mean values are considered, the coal consumption per I.HP. is actually greater with water-tube boilers than with cylindrical boilers, because only two sets of Dürr boilers are used in the comparison, one of which—in the *Baden*, which were the first of the system to be used on board a war ship—from the outset proved themselves to be uneconomical, and because among the small-tube water-tube boilers only one Thornycroft boiler comes into the comparison.

The coal consumption per I.H.P. of the *Bayern*, on the other hand, for continuous steaming is approximately the same as in the ships with cylindrical boilers, viz: 3.064 pounds, as against the mean for the four ships of 2.998 pounds at 9 knots, and 2.359 pounds as against the mean for the four ships of 2.237 pounds, at 12½ knots. The coal consumption of the Schulz boilers in H. I. M. S. *Nymphe* was, so long as the coal lasted, on a full-speed continuous run, as low as 2.171 pounds per I.H.P.

From these figures it will be seen that the reproach of being

uneconomical cannot be indiscriminately applied to all water-tube boilers.

VIII.—EFFICIENCY OF THE VARIOUS SYSTEMS.

1. Calculated on the Basis of Floor Space.—The efficiency of the boilers referred to in this article, calculated on the amount of floor space taken up by them, depends upon the extent of forcing permissible, the grate area which can be fitted with a given boiler-room floor space being almost similar in all the systems. In the ships already fitted with water-tube boilers in the German Navy the amount of grate surface per square foot of boiler-room floor space is as follows:

Type of boiler.	Square feet of grate area.
Schulz	0.177 to 0.267
Dürr	0.18 to 0.278
Cylindrical	0.218 to 0.264
Thornycroft	0.18 to 0.247
Locomotive	0.118 to 0.13

If the space available is restricted, a somewhat larger amount of grate surface can be placed within a given floor space by using Dürr boilers than would be possible if small-tube water-tube boilers with adequate-sized water chambers were selected.

As with cylindrical boilers, the pressure used in the ash pit is less than half an inch (.47 inch), which admits of burning not more than about 24.58 pounds of coal per square foot of grate surface per hour, whilst with the Dürr and Schulz boilers about 37 pounds can be quite conveniently burnt, the efficiency of the cylindrical boilers as compared with the water-tube boilers in question, taking the amount of floor space available in the boiler room, stands about as 2 : 3.

2. Calculated on the Weight.—As regards the weights of boiler installations, these depend considerably upon the amount of forcing the boilers will be subjected to—the smaller the installation is for a given power the less economical will it be for a greater power, because it will then have to be heavily forced, but the installation per I.H.P. will be lighter. A certain limit will be imposed on the makers by the fixing of the maximum coal consumption for the continuous maximum speed runs; the propor-

tions of the boilers for the maximum power of the engines will, however, vary considerably, as the coal consumption is not ascertainable for runs with the maximum power of the engines when the boilers are being forced, only the H.P. per square foot of grate and of heating surfaces being available for the purposes of comparison. From the tabulated details given in Appendix II of the results of trials already carried out with the maximum power of the engines, the following appear to be the powers obtainable:

Type of boiler.	I.H.P.	
	Per square foot of grate surface.	Per square foot of heating surface.
Cylindrical	9.0 to 13.8	.323 to .418
Locomotive	16.2 to 23.7	.313 to .532
Dürr	11.8 to 17.4	.288 to .388
Thornycroft	16.2 to 19.2	.304 to .369
Schulz	15.0 to 17.1	.274 to .334

Nevertheless, the mean values ascertained from the comparative results shown in Appendix II afford a standard for judging the efficiency of the several systems as measured by their weight. According to these mean values the weight of the boiler installations, *i. e.*, the weight of the boilers, with uptakes and funnels, including all the auxiliary engines with their steam and water connections in the boiler room used for working the boilers, stands to the powers obtained, as follows:

Type of boiler.	I.H.P. per square foot—		Lbs. per I.H.P.
	Grate surface.	Heating surface.	
Cylindrical	12.5	.390	161.0
Cylindrical and Schulz	13.6	.328	131.0
Cylindrical and Thornycroft	13.7	.352	130.0
Dürr	14.6	.347	111.0
Locomotive	20.8	.427	106.8
Belleville	12.5	.398	103.2
Niclausse	13.3	.396	91.5
Schulz	16.0	.304	85.5
Thornycroft	17.2	.332	81.2

PRINCIPAL DATA OF BOILERS FOR THE GERMAN NAVY.

Ship.	APPENDIX I. Results with triple-expansion engines.								APPENDIX II. Particulars of the several boiler installations. (The boiler-room weights include boilers, pipes, auxiliary engines, funnels, etc.						
	Contractors' acceptance trials.				Under ordinary working conditions.										
	Continuous maximum speed run.		Ordinary speed.		Continuous maximum speed run.		Ordinary speed.								
	Lbs. of coal per sq. foot of grate.	Lbs. of coal per I.H.P.	Lbs. of coal per sq. foot of grate.	Lbs. of coal per I.H.P.	Lbs. of coal per sq. foot of grate.	Lbs. of coal per I.H.P.	Lbs. of coal per sq. foot of grate.	Lbs. of coal per I.H.P.	Maximum continuous I.H.P. developed.	Total weight of boiler, tons.	Grate surface, sq. feet.	Heating surface, sq. feet.	I.H.P. per sq. foot of grate surface.	I.H.P. per sq. foot of heating surface.	Total weight in lbs. per I.H.P.
I.—Cylindrical Boilers.															
Brandenburg	20.2	1.76	12.0	1.64	19.3	1.82	16.6	2.33	9,863	728	753	24,640	13.1	.400	165.6
Kurfurst Friedrich Wilhelm	18.5	1.74	12.9	1.83	17.2	1.89	15.2	2.42	9,850	732	753	24,640	13.0	.398	166.7
Weissenburg	18.6	1.66	12.3	1.74	19.0	1.85	16.6	2.29	9,964	717	753	24,640	13.2	.402	161.5
Worth	19.2	1.73	9.7	1.58	17.0	2.11	14.4	2.10	10,330	693	753	24,640	13.7	.418	150.0
Kaiserin Augusta	14.7	1.88	12.0	1.99	20.6	1.94	11.8	1.84	14,310	905	1,033	35,700	13.8	.400	141.5
Gefion	16.0	1.73	10.7	2.22	23.1	2.08	...	...	9,116	598	715	22,700	12.7	.402	147.0
Cormoran	20.5	1.96	16.1	2.62	17.0	2.7	...	...	2,816	203	224	7,534	12.5	.374	162.1
Condor	18.3	2.07	10.2	1.69	16.9	2.85	...	...	2,840	193	226	7,050	12.5	.402	152.0
Geier	15.5	1.79	13.4	2.2	14.6	2.7	...	...	2,920	209	226	7,050	12.9	.415	161.0
Pelican	14.2	1.81	4.65	1.87	...	...	...	...	3,028	219	258	8,400	1.7	.361	161.8
Buzzard	20.7	2.29	12.8	2.72	...	...	16.5	3.22	2,770	213	226	7,150	12.2	.384	173.0
Hohenzollern	12.5	1.95	...	...	16.8	2.04	...	...	9,325	778	1,033	28,800	9.0	.323	187.5
* *Mean*	*17.4*	*1.86*	*11.5*	*2.01*	*18.2*	*2.2*	...	...	...	...	...	...	*12.5*	.390	*161.0*
II.—Locomotive Boilers.															
Siegfreid	18.1	1.97	6.7	1.87	29.7	3.17	...	...	4,725	200	232	10,763	20.4	.438	95.2
Beowulf	23.9	1.77	15.9	1.87	...	...	...	...	4,810	222	219	11,850	22.0	.406	103.8
Frithjof	29.2	1.99	17.6	2.18	...	...	...	...	4,900	221	219	11,850	22.3	.412	101.2
Hildebrand	35.3	2.15	19.0	2.57	...	...	...	...	5,260	220	222	9,850	23.7	.532	93.8
Heimdall	30.2	1.92	18.1	2.27	...	...	...	...	4,336	231	213	10,610	20.2	.408	120.0
Hagen	31.4	1.87	...	...	...	...	...	...	4,452	240	213	10,610	20.9	.42	120.8
Odin	24.9	1.94	9.05	2.4	...	...	...	...	3,481	243	215	10,615	16.2	.328	156.0
Hela	28.8	1.89	17.3	2.19	...	...	...	...	5,925	237	281	12,500	21.1	.472	89.8
Wacht	28.6	1.82	...	...	...	...	...	...	...	...	...	...	...	...	...
Jagd	40.0	2.29	...	...	26.5	1.81	...	...	3,430	169	162	11,000	21.0	.313	110.9
Comet	28.1	1.92	16.7	2.26	...	...	...	...	...	...	...	...	...	...	...
Meteor	19.9	2.22	14.0	2.57	...	...	...	...	4,676	157	232	9,200	20.1	.508	75.2
* *Mean*	*28.2*	*1.98*	*14.0*	*2.23*	...	...	...	...	...	...	...	...	*20.8*	.427	*106.8*

III.—Durr Boilers.

Baden	19.6	2.0	15.0	2.32	22.4	2.62	20 4	2.94	6,118	347	517	16,750	11.8	.366	127.0
Bayern	17.2	1.56	14.0	1.97	26.6	2.28	20.6	2.39	6,280	348	454	21,800	13.8	.288	124.5
Sachsen	23.06	2.06	...	...	23.3	1.98	...	...	6,370	323	437	18,250	14.5	.348	113.6
Victoria Luise	19.2	1.99	13.9	1 86	...	...	...	...	10,420	408	674	29,850	15.4	.346	88.2
Vineta	...	...	13.2	2.08	...	...	...	...	10,500	472	600	27,000	17 4	.388	101.0
* *Mean*	*19.7*	*1.91*	*14 0*	*2.06*	*24.1*	*2.29*	...	...	...	...	...	...	*14.6*	*.347*	*111.0*

IV.—Thornycroft Boilers.

Ægir	22.4	1.69	10.4	2.15	24.5	1.94	23.9	3.32	4,909	192	274	16,150	17.9	.304	87.6
Three days' run	...	...	...	...	28.6	2.08	25.0	2.72	...	...	...	...	...	..	...
Iltis	24.9	1.60	21.8	1.99	...	...	...	...	1,358	466	818	4,098	16.6	.331	77.0
Jaguar	24.9	1.69	19.7	1.84	...	...	...	...	1,358	471	818	4,098	16.6	.331	77.7
Tiger	30.1	2.79	21.6	3.31	...	...	...	...	1,351	541	818	4,098	16.5	.331	90.0
Luchs	28.6	2.12	16.4	2.9	...	...	...	...	1,325	542	818	4,098	16.2	.324	91.6
Niobe	17.4	1.89	19.0	2 16	...	...	...	...	8,000	226	416	2,176	19.2	.369	63.2
* *Mean*	*23.0*	*1.79*	*17.5*	*2.21*	...	...	...	...	...	...	...	...	*17.2*	*.332*	*81.2*

V.—Schulz Boilers.

Wurttemberg	26.9	2.29	21.6	2.23	26.6	2.51	...	...	6,177	292	412	22,500	15.0	.274	106.0
Nymphe	...	...	11.8	1.67	...	...	...	...	8,375	243	488	25,000	17.1	.334	65.3
Three days' run	26.6	2.10	...	...	...	...	...	...	...	...	...	...	...	...	...
* *Mean*	*26.7*	*2.18*	*16.7*	*1.96*	...	...	...	...	...	...	...	...	*16.0*	*.304*	*85.5*

VI.—Niclausse Boilers.

Gazelle	15.4	1.81	12.4	1.93	...	...	...	...	6,275	252	462	15,650	13.6	.402	90.0
Freya	...	...	...	...	...	...	...	...	10,200	417	775	25,850	13.0	.390	92.7
* *Mean*	...	...	...	...	...	...	...	...	...	...	...	...	*13.3*	*.396*	*91.5*

VII.—Belleville Boilers.

Hertha	17.5	2.03	7.65	2.17	19 2	2.18	13.5	3.94	10,050	449	795	24,000	12.6	.400	100.5
Hansa	16.6	1.99	8.6	1.85	...	...	...	...	9,928	472	795	24,000	12.4	.395	106.8
* *Mean*	*17.1*	*2.01*	*8.12*	*2.01*	...	...	...	...	...	...	...	...	*12.5*	*.398*	*103.2*

VIII.—Mixed System.—Cylindrical—Thornycroft.

Kaiser Friedrich III	14.1/21.9	1.84	...	...	18.1/35.4	2.54	...	...	12,860	593 154	655 280	23,280 13,250	13.7	.352	130.0

IX.—Mixed System.—Cylindrical—Schulz.

Kaiser Wilhelm II	14.0/20.7	1.82	...	...	...	...	...	...	...	...	...	...	...	...	...
Furst Bismarck	...	...	...	...	...	...	...	...	13,420	785	655 327	23,500 17,450	13.6	.328	131.0

The figures given in the table of Appendix II also show approximately how much more weight can be spared by using the various boiler systems if the work done by the boiler is further increased. For this, however, the statements of the coal consumption shown in the tables of Appendix I for continuous maximum speed runs with all the boilers at work must be taken into consideration, because these values have a close connection with the powers obtained from the boilers, whereas when running at ordinary speed as many boilers can be used as are required to prevent the work done by any single boiler being too great.

It is evident that the values of the weight of each individual boiler installation per I.H.P. is affected by the efficiency of the engines, and also by all the little contingencies met with in the trial runs, and by the greater or lesser skill of the stokers; it would therefore be expedient to obtain a larger amount of data from which to draw comparisons in order to obtain more reliable mean values. According to the data in regard to weights here collected, the choice of a mixed boiler installation on board battleships leads to a saving in weight of $\frac{158.7 - 128.6}{158.7}$ = about 20 per cent. over an installation of cylindrical boilers only. For this class of ship this represents some 190 tons, which can be utilized either in coals, thereby increasing the radius of action, or in some other way. By the installation of Dürr boilers a further saving of some 19 pounds per I.H.P. would be effected, which, with 15,000 I.H.P., would mean a further gain of some 120 tons; if Schulz boilers were to be chosen the saving in weight over mixed boilers would be some 44 pounds per I.H.P., equal to a further reduction of about 270 tons.

IX.—COST OF THE VARIOUS SYSTEMS.

It is difficult to ascertain the cost of the various systems of boilers, because those in the Imperial yards have been constructed at various times, and, consequently, under varying conditions of trade and of the labor market, etc., whilst, on the other hand, the tenders from private yards seldom give any details that can

be used for purposes of comparison. Again, the cost per I.H.P. is greatly influenced by the amount of forcing the boilers can be subjected to, and also by the efficiency of the engine installation.

In order to be able to form a rough estimate, a few figures are given as to the cost of some installations. The Schulz boiler installation for H. I. M. S. *Württemberg* cost £26,613 15s. These boilers are very lightly worked; if *they were to be forced approximately to the same extent as* in the case of H. I. M. S. *Nymphe* on the occasion of her six hours' acceptance trial under forced draft, *i. e.*, to a development of 17.58 I.H.P. per square foot of grate area, and .315 I.H.P. per square foot of heating surface, the steam generated would be sufficient to develop 7,100 I.H.P., making the cost of the boiler installation about £3 15s. per I.H.P.; this figure is approximately the same as the estimate of the Schiff und Maschinenbau-Aktien-Gesellschaft Germania for a Schulz boiler installation.

The cylindrical boilers in the mixed installation on board H. I. M. S. *Kaiser Friedrich III* on the six hours' official trial when the engines developed 13,000 I.H.P., are credited with a development of about 13 I.H.P. per square foot of grate surface; if, however, an air pressure of only .47 inch is used and the consequent development attained is not more than 11.61 I.H.P. per square foot of grate area, and .325 I.H.P. per square foot of heating surface, then the power developed by the cylindrical boilers would be only 7,600 I.H.P. As this part of the installation cost £32,950, the cost per I.H.P. on this assumption would be about £4 6s. 8d.

An installation of Dürr boilers, if the arithmetical mean is assumed as being correct, would, according to the last tenders submitted by private firms, cost about £3 10s. per I.H.P. By taking other data for working out the calculations, the difference in price, however, comes out extremely small, the Dürr boilers in certain cases even coming out somewhat dearer than cylindrical and Schulz boilers. According to a report from the Imperial Yard at Kiel, the following prices have been paid for the boilers, with casing plates and lagging, of the ships built at the yard during the last few years, viz: For cylindrical boilers, £1 15s. 4d.;

for Dürr boilers, £1 11s. 6d. to £2 0s. 11d.; for Schulz boilers, £1 15s. 7d. to £1 16s. 10d., calculated on the I.H.P. contracted for.

X.—CONCLUDING REMARKS.

From the foregoing it will be seen that the decision of the German Navy to construct Schulz and Dürr boilers whilst carrying out experiments with other systems has been attended with satisfactory results. We may well be contented with the success hitherto attained, and the time may, perhaps, not be far distant when the other naval Powers will follow in our footsteps. We began to build water-tube boilers somewhat later than other countries, but it is now recognized abroad that we have consistently progressed, and have now come to the front of other nations, who begin to see that their selection from the various systems has been so unlucky that they have now to search for a better type of water-tube boiler.

It is not improbable that further experience may lead to the adoption altogether of water-tube boilers, and that one type may prove better than the other. For the present, however, the principle has been adopted to fit gunboats and small cruisers, where saving of weight is of special consequence, with Schulz boilers, large cruisers with Dürr boilers, and battleships, which can stand heavy boiler installations somewhat better, with cylindrical and Schulz boilers.

THE BALANCE OF A FOUR-CYLINDER, TRIPLE-EXPANSION MARINE ENGINE.

By Harvey D. Williams.

The following is an investigation of the possible causes of vibration in a marine engine of a type quite generally used, that is, a triple-expansion engine having two low-pressure cylinders, cranks 90 degrees apart (Fig. 1), the two low-pressure cranks being opposite, and the order of the cylinders from forward being H.P., I.P., 1st L.P., 2d L.P. In this particular engine no attempt was made to balance the inertia effects beyond an adjustment of weights. The torsional effort on the shaft as influenced by the apportionment of work among the four cylinders is also quite irregular. The controlling factors in the design were evidently high power and light weight, and it is this, mainly, that gives interest to the results of the investigation and justifies their publication.

CRANK EFFORT DIAGRAM.

The torsional effort on the crank shaft fluctuates as a result of the varying rates with which the steam does work in the cylinders and also as a result of the transfer of kinetic energy to and fro between the rotating and reciprocating parts. The variation due to the former cause is independent of the speed of the engine, while the latter is proportional to the square of the revolutions. In the usual text-book method of constructing torque diagrams the two effects are treated together, but in the following analysis they are kept separate.

First, then, neglecting the inertia effects, we start from the indicator cards (Fig. 2), from which are derived the curves of the piston rod effort (Fig. 3). The calculations involved in making this step are indicated in the following table:

Port engine.
Data concerning unbalanced moving weights.

FIG. 1.

.....	H.P.	I.P.	1st and 2d L.P.
Net piston areas in square inches, average top and bottom.....	150.4	376.59	497.2
Scale of indicator spring, pounds per inch..	150	60	20
Scale by which ordinate of indicator card will measure pounds of total effort on piston rod, pounds per inch.....	22,560	22,595	9,944
Inch pounds of torque per pound of tangential effort on crank pin = radius of crank = ...	9	9	9
Desired scale of torque, 1 inch = 200,000 inch pounds. Change of indicator card ordinates by proportional dividers that will result in the desired scale of torque....	1 to 1.015	1 to 1.017	1 to .4475

The last value in the H.P. column is found as follows:

$$\frac{22,560 \times 9}{200,000} = 1.015,$$

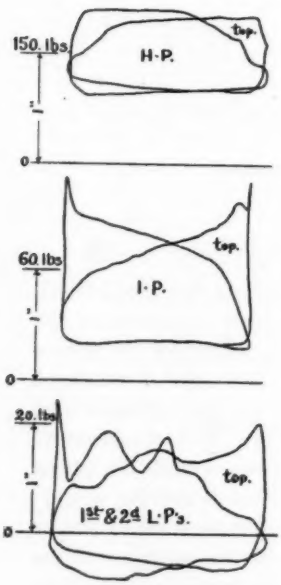
and similarly for the other columns.

To draw the H.P. curve of piston-rod efforts the proportional dividers are set so that an ordinate of 1 inch measured on the indicator card will give an ordinate of 1.015 inches for the piston-rod effort curve. The ordinate of the indicator card is measured from the high-pressure line of one end to the back-pressure line of the opposite end; and the ordinate of the curve of piston-rod effort is laid off from the horizontal line upward while the piston is moving up, and downward while the piston is moving down.

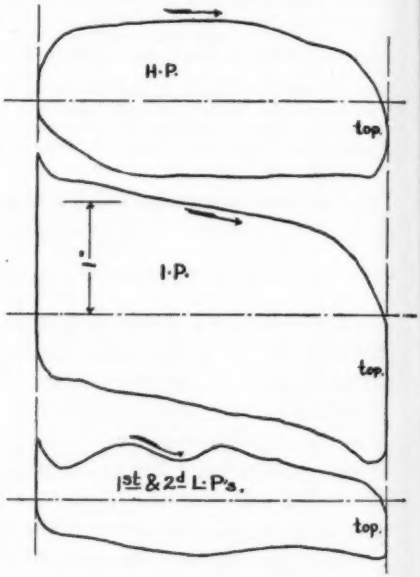
While the ordinates are brought to a uniform scale by means of the proportional dividers the lengths of the cards are at the same time stretched or compressed to a dimension representing the stroke of the engine to a convenient scale. The distribution of work among the four cylinders is correctly represented by the areas of the curves in Fig. 3. It should be noted, however, that the low-pressure curve is the curve for *each* of the low-pressure cylinders and not for both of them, as might be supposed.

The horizontal axis of the piston-rod effort curve is now conceived to represent the to-and-fro path of the center of the cross-head pin, and this conception is carried further by drawing the crank circle in its proper relative position. The curve of tangential effort on the crank pin is now derived from the piston-

rod effort curve by a graphical process which may be briefly described as follows: For each position of the moving parts draw two lines parallel to the connecting rod, making the distance between the two lines (one of which is conveniently the connecting rod itself) such that the length intercepted on the crank radius



Indicator cards at 385 R.P.M.
FIG. 2.



Piston rod efforts at 385. R.P.M.
(curves derived from indicator cards)
Scale 1" = $\frac{200,000}{9}$ lbs on piston rod.
FIG. 3.

measures the piston-rod effort. The length intercepted on a line perpendicular to the cylinder axis will then measure the crank-pin effort. The curves of tangential effort on the crank pin are likewise the curves of moment about the crank shaft. They are shown in Fig. 4. Considered as curves of moment the scale is 1 inch = 200,000 inch pounds, while considered as curves of crank-pin effort the scale is 1 inch = (200,000 ÷ 9) pounds. The ratio between these scales is numerically equal to the radius of

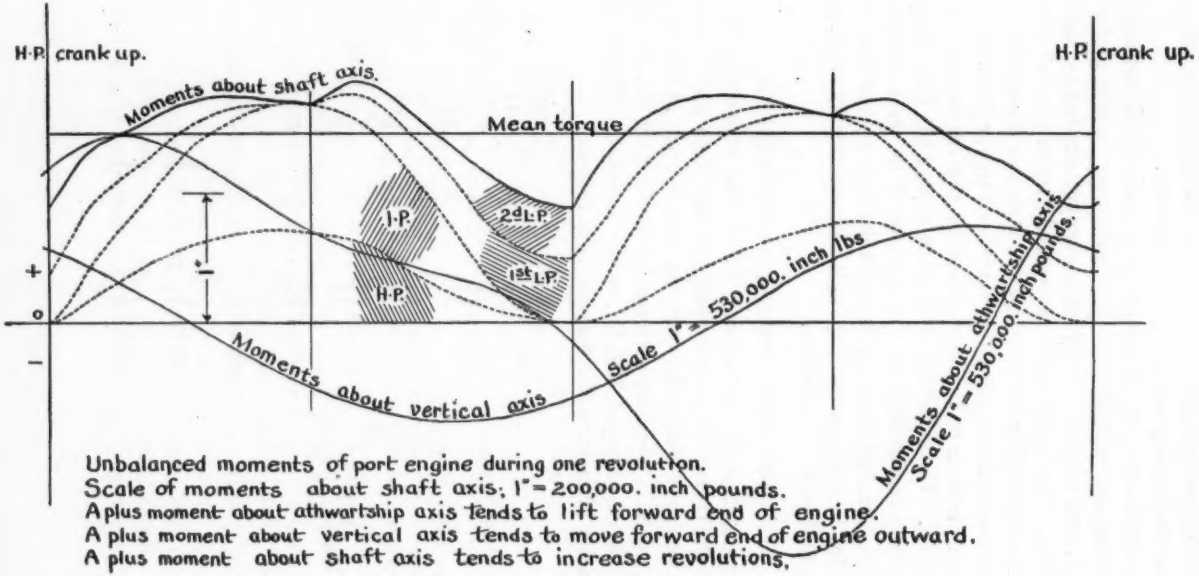
the crank (9 inches), which is as it should be, since, for each pound of effort there are 9 inch pounds of moment.

The efforts exerted by the several cranks are shown superimposed one above another so that the upper border line of the 2d L.P. area is the curve of total moment exerted by the four cylinders. The horizontal line marked "mean torque" is of the same average height as the curve of "moments about shaft axis," and the area underneath either line down to the horizontal zero line is a measure of the work done by the engine during one revolution. The distribution of work among the four cylinders is correctly represented by the portions of the area assigned to each cylinder, and the irregularity in the top curve is clearly seen to be due in large part to the small amount of work apportioned to the low-pressure cylinders.

UNBALANCED TORSIONAL INERTIA MOMENTS.

The variation of the torsional effort that necessarily accompanies the transfer of kinetic energy to and from parts of the engine that move with widely varying speeds, such as the reciprocating parts, is found by an equation derived by Mr. Macalpine and given on page 508, Vol. IX, of this JOURNAL. That equation with a few changes in the notation is as follows:

$$T = \frac{WR^2N^2}{422{,}800} \times \begin{cases} -\sin\theta\left(\frac{a}{4} + \frac{a^3}{16} + \frac{15a^5}{512} + \text{etc.}\right) \\ +\sin 2\theta\left(\frac{1}{2} + \frac{a^4}{32} + \frac{a^6}{32} + \text{etc.}\right) \\ +\sin 3\theta\left(\frac{3}{4}a + \frac{9a^3}{32} + \frac{81a^5}{512} + \text{etc.}\right) \\ +\sin 4\theta\left(\frac{a^2}{4} + \frac{a^4}{8} + \frac{a^6}{16} + \text{etc.}\right) \\ -\sin 5\theta\left(\frac{5a^3}{32} + \frac{75a^5}{512} + \text{etc.}\right) \\ -\sin 6\theta\left(\frac{3a^4}{32} + \frac{3a^6}{32} + \text{etc.}\right) \\ +\sin 7\theta\left(\frac{21}{512}a^5 + \text{etc.}\right) \\ +\sin 8\theta\left(\frac{a^6}{32} + \text{etc.}\right) \end{cases} \quad \ldots\ldots (1)$$



Unbalanced moments of port engine during one revolution.
Scale of moments about shaft axis; 1" = 200,000. inch pounds.
A plus moment about athwartship axis tends to lift forward end of engine.
A plus moment about vertical axis tends to move forward end of engine outward.
A plus moment about shaft axis tends to increase revolutions.

FIG 4.

in which T = moment (torque) in inch pounds, a plus moment being one that tends to increase the revolutions of the engine.

W = weight of piston, piston rod, crosshead and one-half weight of connecting rod.

R = radius of crank in inches.

N = revolutions per minute.

a = length of crank divided by length of connecting rod.

θ = angular position of crank measured from the upper dead center.

Substituting the value of $a = 9 \div 40$ in equation (1), we have

$$T = \frac{WR^2N^2}{422{,}800} \times \begin{cases} -.0570 \sin\theta \\ +.5001 \sin 2\theta \\ +.1720 \sin 3\theta \\ +.0144 \sin 4\theta \\ -.0019 \sin 5\theta \\ -.0003 \sin 6\theta \\ \text{etc.}, \ldots\ldots\ldots \end{cases} \quad (2).$$

In this formula R = 9 and N = 385. The further application of the formula to the case in hand is facilitated by the use of a table as follows:

	2d L.P.	1st L.P.	I.P.	H.P.	Vector sum or resultant for four cylinders.
W. =	353.5	353.5	368.5	304.5	
$\frac{WR^2N^2}{422{,}800}$ =	10,050	10,050	10,450	8,650	
" $\times -.0570 \sin\theta$ =	−572. W.	−572. E.	−596. S.	−493. N.	103. N.
" $\times +.5001 \sin 2\theta$ =	5,026. S.	5,026. S.	5,230. N.	4,325. N.	497. S.
" $\times +.1720 \sin 3\theta$ =	1,727. E.	1,727. W.	1,798. S.	1,487. N.	311. S.
" $\times +.0144 \sin 4\theta$ =	145. N.	145. N.	150. N.	125. N.	564. N.
" $\times -.0019 \sin 5\theta$ =	−19. W.	−19. E.	−20. S.	−16. N.	4. N.
" $\times -.0003 \sin 6\theta$ =	−3. S.	−3. S.	−3. N.	−2. N.	1. N.
					136. S.

Before leaving the table it will be necessary to explain the significance of the letters N, E, S and W. They are simply the abbreviations of the words north, east, south and west, and are introduced into the table as being more concise and more easily

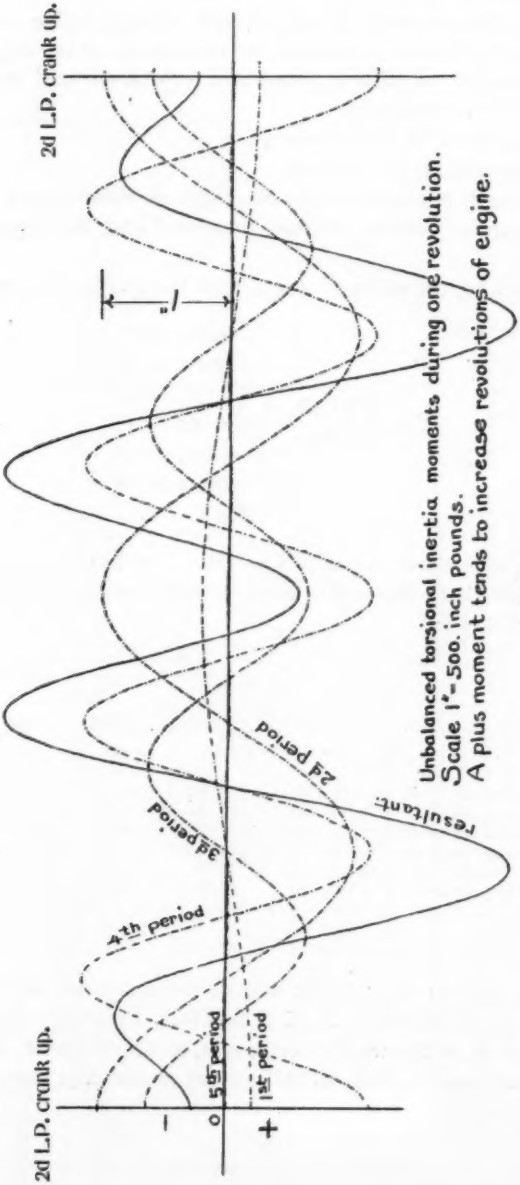

2d L.P. crank up.
1"
Unbalanced torsional inertia moments during one revolution.
Scale 1"=500. inch pounds.
A plus moment tends to increase revolutions of engine.
Resultant
2d period
3d period
4th period
5th period
1st period
2d L.P. crank up.
−
0
+

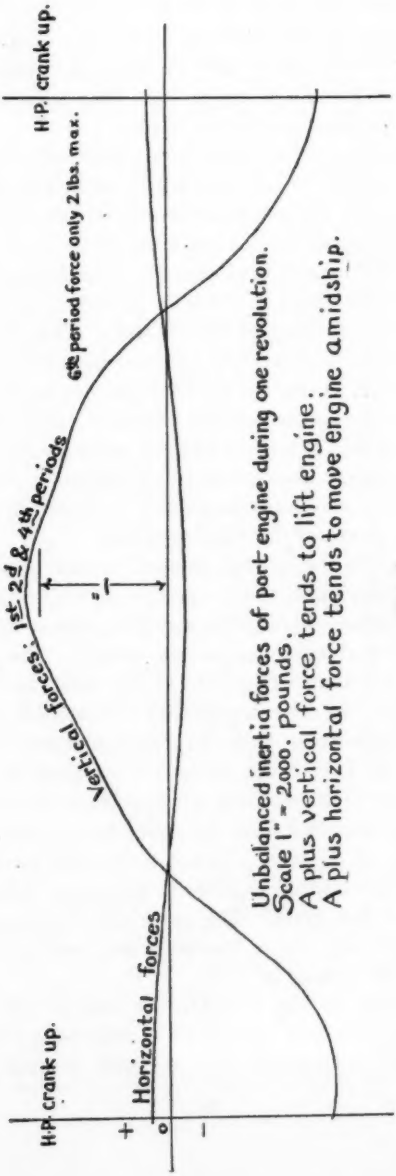
FIG. 5.

interpreted than the symbols *sin* θ, *sin* 2θ, etc. Referring to Fig. 1, and applying the conventions of an ordinary map to the part marked "view looking aft" we have H.P. crank north, 1st L.P. crank east, I.P. crank south, etc., thus corresponding with the letters in the first line of the table.

Doubling the angle that each crank makes with the H.P. crank, we have H.P. north, 1st L.P. south, I.P. north and 2d L.P. south, corresponding with the letters in the second line of the table. As we multiply the crank angles successively by 1, 2, 3, 4, etc., the result for the H.P. crank is always N, since the angle is initially 0. The result for the I.P. crank is N and S alternately, each increase in the angle being of 180 degrees. The effect of a minus sign is to reverse the direction denoted by a letter, thus — S is the same as + N, so that all minus signs are readily eliminated. The nature of the vector sum or resultant will be made clear if we simply read into the third line, for example, of the table, the following meaning. If we travel east a distance 1,727, then travel 1,727 west, then 1,798 south, and finally 1,487 north, we will arrive at a point 311 south of the starting point.

We now have in the column headed "vector sum" a complete definition or description of the unbalanced torsional inertia moments. The values there given are the greatest values attained by the moments of each component period. They are not attained at the positions designated in the table, however, but 90 degrees from it. In other words they are attained after the shaft has made a quarter turn from the position shown in Fig. 1, that is, when the 2d L.P. crank is up. According to the formula each component of the moment is proportional to the *sine* of some angle which is measured from the upper dead center. The maximum *sine* is at 90 degrees. Hence, to find the position of maximum moment we add 90 degrees to the angle indicated in the last column of the table. The same result is more easily obtained, however, by simply marking the ends of our diagram (Fig. 5), 2d L.P. instead of H.P.

Referring, now, to Fig. 5 and to the vertical line marked "2d L.P. crank up," the first period curve intersects that line at the point properly designated as +103 inch pounds, the second



Unbalanced inertia forces of port engine during one revolution.
Scale 1" = 2,000. pounds.
A plus vertical force tends to lift engine.
A plus horizontal force tends to move engine amidship.

FIG. 6.

period curve at the point —497 inch pounds, the third period curve at the point —311 inch pounds, etc., and the resultant at the point —136 inch pounds. And these are the proper interpretations of the values given in the column headed "vector sum" in the table.

The points thus located are the starting points of the component curves marked 1st period, 2d period, etc. The curves themselves are simply projections of helices, the first one being a helix of one turn per revolution of the shaft, the second, a helix of two turns; the third of three turns, etc. The ordinates of the resultant curve are found graphically by taking the algebraic sums of the ordinates of the component curves, as was illustrated by the determination of the starting point of the resultant curve, —136 inch pounds.

The resultant curve in Fig. 5, gives a complete history of the variations of the torsional inertia moments during one revolution. If this curve is re-plotted to the scale used in Fig. 4, which is 400 times finer than that of Fig. 5, the fluctuations become so small as to be practically invisible. The tortional inertia moments can therefore be neglected in comparison with the fluctuations of moment due to the unequal distribution of work in the cylinders.

VIBRATIONS OF SHAFT AXIS.

So far, we have examined only those influences that tend to make the engine vibrate rotatively about the engine shaft as an axis. We have now to examine those influences that tend to disturb the position of the shaft axis itself. These influences comprise the unbalanced revolving weights and the unbalanced reciprocating weights. For the purpose of this analysis the revolving weights may be considered as concentrated in a point at the center of the crank pin, and the reciprocating weights may be regarded as concentrated in a point at the center of the crosshead pin. There will thus be two weights to consider for each connecting rod in the engine. Each reciprocating weight comprises piston, piston rod, crosshead and as much of the connecting rod as would come on the crosshead pin if the connecting rod were held in a horizontal position, being supported at the

crank-pin and crosshead-pin centers. Each revolving weight comprises the crank pin, the remainder of the connecting rod, and as much of the crank webs as would come on the crank-pin center if the webs were held in horizontal positions, being supported at the crank-pin center and shaft center. It will be seen that the weight of the connecting rod is divided in such a way as to leave the position of its center of gravity unchanged. This is strictly correct for the analysis that we are now making, but it is not correct to divide the rod in that manner when dealing with the torsional inertia moments.*

The collected weights, as defined, together with necessary dimensions, are given in Fig. 1.

HORIZONTAL FORCES AND MOMENTS.

These are due to the revolving weights alone. They are not complicated by the angularity of the connecting rod, and hence are wholly of the first period. This means that in our diagram each will be represented by the projections of a simple helix of one turn per revolution of the shaft. The forces tend to move the shaft bodily athwartship and the moments tend to rotate the shaft about a vertical axis.

Horizontal Forces.—The maximum value of the horizontal force due to each revolving weight is equal to its centrifugal force,

$$F = \frac{WRN^2}{35{,}235}, \quad \ldots\ldots\ldots \quad (3)$$

in which

F = maximum horizontal force in pounds.
W = revolving weight in pounds.
R = radius of crank in inches.
N = revolutions per minute.

Using the weights given in Fig. 1, we have—

*This last case, which is far more complex, will be found fully treated by Mr. Macalpine in Vol. IX of this JOURNAL with the results stated on pp. 45 and 517.

	2d L.P.	1st L.P.	I.P.	H.P.	Vector sum.
W = ...	286	278.5	294.5	294.5	
$F = \frac{WRN^2}{35,235} =$	10,820. W.	10,530. E.	11,140. S.	11,140. N.	290. W.

The vector sum, 290. W., signifies that in the view looking aft (Fig. 1), and with the cranks in the position shown, the shaft is urged towards the west (amidship) by a force of 290 pounds. This horizontal force may be regarded as the horizontal component of the centrifugal force exerted by a single revolving weight. From this it is clear that the horizontal force must pass through the series of changes shown in Fig. 6 during each revolution of the shaft.

Horizontal Moments.—The revolving weights are not all in the same plane of rotation, and consequently their centrifugal forces give rise to couples which tend to disturb the parallelism of the shaft axis. We will now consider the moments tending to disturb this parallelism in a horizontal plane. The lever arm of each force will be (see Fig. 1) the perpendicular distance from its plane of action to the center line of the after low-pressure cylinder. The choice of the after low-pressure cylinder as a plane of reference is arbitrarily made, since the result is not affected by this choice. All lever arms must, however, be measured from the *same* plane.

Tabulating as before, we have:

	1st L.P.	I.P.	H.P.	Vector sum.
F = force in pounds.....	10,530. E.	11,140. S.	11,140. N.	
l = lever arm in inches.....	29½	57½	80½	
Fl = moment in inch, pounds,	308,000. E.	644,000. S.	900,000. N.	308,000. E. 256,000. N.

The 2d L.P. column does not appear in this table, for the reason that its lever arm, and consequently its moment, = 0, and so does not affect the result. The vector sum, 308,000 E and 256,000 N, is the same as $\sqrt{308,000^2 + 256,000^2} = 400,000$ in a northeasterly direction—more precisely 40 degrees north of east. The magnitude and direction of the vector sum are both readily

found by simply laying off the base and height of a right-angled triangle, and then measuring the length and direction of the hypothenuse. Referring again to the "view looking aft" in Fig. 1, the interpretation of our result is as follows: the maximum value of the moment tending to rotate the shaft about a vertical axis is 400,000 inch pounds. In the position shown in Fig. 1 the tendency is to turn the forward end of the shaft outward (toward the east) but the shaft, as shown, has rotated 40 degrees past (toward the north) the position where the moment is a maximum. When the H.P. crank is up the moment is therefore diminishing, a fact that is shown graphically by the downward initial slope of the curve labeled "moments about vertical axis" in Fig. 4.

VERTICAL FORCES AND MOMENTS.

These are due to both revolving and reciprocating weights for the first period, and to the reciprocating weights alone for the higher periods. The vertical and horizontal effects of the revolving weights are equal, and, since, as already noted, the motions of the revolving weights are not complicated by the angularity of the connecting rod, these weights do not appear as factors in the determination of the higher-period components.

Vertical Forces.—For our equation we are again indebted to Mr. Macalpine (p. 506, Vol. IX).

$$F = \frac{RN^2}{35{,}235} \times \begin{cases} (W+W_1)\cos\theta \\ +W_1 \begin{cases} \cos 2\theta \left(a + \frac{a^3}{4} + \frac{15a^5}{128} + \text{etc.}\right) \\ -\cos 4\theta \left(\frac{a^3}{4} + \frac{3a^5}{16} + \text{etc.}\right) \\ +\cos 6\theta \left(\frac{9a^5}{128} + \text{etc.}\right) \end{cases} \end{cases} \quad . \quad . \quad . \quad . \quad (4)$$

in which F = vertical force in pounds.
W = revolving weight in pounds.
W_1 = reciprocating weight.
R = radius of crank in inches.
N = revolutions per minute.
a = length of crank divided by length of connecting rod.

θ = angular position of crank measured from upper dead center.

Substituting the value of $a = 9 \div 40$ in equation (4), we have

$$F = \frac{RN^2}{35{,}235} \times \begin{cases} (W+W_1)\cos\theta. \\ +W_1 \begin{cases} +.2279 \cos 2\theta. \\ -.0030 \cos 4\theta. \\ +.00004 \cos 6\theta. \end{cases} \end{cases}$$

Substituting the values $R = 9$ and $N = 385$, and tabulating our results we have:

	2d L.P.	1st L.P.	I.P.	H.P.	Vector sum or resultant for four cylinders.
W =	286	278.5	294.5	294.5	
W_1 =	309.5	309.5	324.	260.	
$W+W_1$ =	595.5	588.	618.5	554.5	
$\frac{RN^2}{35{,}235}(W+W_1)\cos\theta$ =	22,530. W.	22,240. E.	23,390. S.	20,975. N.	290. W. / 2,415. S.
$\frac{RN^2W_1}{35{,}235} \times +.2279 \cos 2\theta$ =	2,669. S.	2,669. S.	2,790. N.	2,240. N.	308. S.
" $\times -.0030 \cos 4\theta$ =	−35. N.	−35. N.	−37. N.	−30. N.	137. S.
" $\times +.00004 \cos 6\theta$ =	.4 N.	.4 N.	.5 N.	.4 N.	2. N

The last column gives the maximum value of the vertical force for each period and its direction at the instant when the H.P. crank is up. The primary force is the only one inclined to the vertical. By drawing the right-angle triangle, as indicated, and measuring its hypothenuse, we find the maximum value of the primary force to be 2,430 pounds and its direction to be 7 degrees west of south. From the direction of rotation it will be seen that a further rotation of 7 degrees from the position shown in Fig. 1, will bring the shaft to the position where the primary force attains its maximum value. With this knowledge it is a simple matter to draw a helical curve that will exhibit all the changes of the primary force during a revolution. Other curves are then drawn showing the changes of the high-period forces, and, finally, the resultant (Fig. 6) shows the combined effect of all vertical forces. It will be noted that there are no third, fifth,

or other odd-period forces except the first. This effect is brought about by the symmetry of the engine, that is, the symmetry of the crank circle with respect to the cylinder axis.

Vertical Moments.—Taking the vertical forces as given in the last table and further tabulating, we have—

	1st L.P.	I.P.	H.P.	Vector sum or resultant moment for four cylinders.
Primary vertical force =.....	22,240. E.	23,390. S.	20,975. N.	
Lever arm of same = l =.....	29¼ E.	57¼ S.	80¼ N.	
Primary vertical moment.....	651,000. E.	1,352,000. S.	1,694,000. N.	{ 651,000. E. { 342,000. N.
Vertical force due reciprocating weights alone = F' =.....	11,710. E.	12,250. S.	9,835. N.	
Corresponding moment = Fl =	342,000. E.	708,000. S.	794,000. N.	
Fl × .2279 *cos* 2θ = secondary vertical moment.....	78,100. S.	161,500. N.	181,000. N.	264,400. N.
Fl × − .0030 *cos* 4θ = 4th period vertical moment =.....	− 1,028. N.	− 2,125. N.	− 2,382. N.	5,535. S.
Fl × .00004 *cos* 6θ = 6th period vertical moment =.....	14. N.	28. N.	32. N.	74. N.

The equivalent of 651,000 E. + 342,000 N., that is, the maximum value of the primary vertical moment, is 736,000 inch pounds; and its direction, 28 degrees north of east, is such that the shaft must revolve 62 degrees past the position shown in Fig. 1 before the primary moment attains this maximum value.

The curve showing the changes during one revolution of the resultant of all vertical moments (Fig. 4) is found by drawing the helical curve for each period and then adding together their ordinates to get the ordinates of the resultant.

The ratio of the length to the breadth of the engine foundation (Fig. 1) is 2.65 : 1 = 530,000 : 200,000. This is also the ratio of the scales used in plotting the curves in Fig. 4. The stability of the engine with reference to vertical and torsional moments, being assumed as roughly proportional to the length and breadth respectively of the engine foundation, we can, by plotting the moments to proportional scales, get a better comparison of them as possible causes of vibration.

CONCLUSIONS.

When the engine was actually tried the only serious vibration that developed was a torsional one, which, as our analysis shows, was almost wholly due to the faulty apportionment of work among the four cylinders. The absence of other vibrations, particularly of a fore-and-aft rocking motion, shows that the engine was fortunately located with reference to the nodes of the vessel.

THE CORRECT TREATMENT OF STEEL.

By Mr. C. H. Ridsdale, F.I.C. (Middlesbrough).

[Paper read before the International Engineering Congress, Glasgow, 1901. Section V: Iron and Steel.]

SECTION I.—PRELIMINARY REMARKS.

The ultimate requirement of steel* is that, when manufactured, it shall in every respect satisfy the purpose for which it is intended; and provided it does this thoroughly, it matters nothing what its composition is, or how it has been treated.

If it does not, the questions arise, Why does it not? Who shall take steps to remedy it? And, What shall those steps be?

Although we are still far from understanding the causes in detail in every case which may produce a certain condition† in steel, much has been learnt during the last few years on these questions; but (as one correct principle actually practised is worth ten reposing in the brains of scientific men) how many of those who handle steel are making full use in practice of what is known as to the effects of various treatment?‡ If not, is it not because our science has not been sufficiently made to face prac-

* The writer in the main has in mind soft steel (such as he has dealt with in his previous papers, "Brittleness in Soft Steel," May, 1898, and "Practical Microscopic Analysis," August, 1899), though the remarks apply largely to all steel up to 0.40 per cent. or 0.45 per cent. carbon, and these harder varieties are specially mentioned in places. He does not refer to steel of any one make or process.

† It is always desirable, in order to give convincing evidence as to cause, to be able to reproduce the effect at will from conditions of actual practice. This (for want of opportunity for minute observation of the daily conditions of practice over a long period) it may not always be possible to do, although the general direction may be suggested. Generally, however, this is not regarded as sufficiently convincing.

‡ By "treatment" is meant everything which it undergoes (as contradistinct to composition), whether physical, thermal, mechanical, &c.

tice, and should not these subjects be discussed more with this in view?

The writer has considered these questions in order to see how our present knowledge, so far as he knew, was or could be applied to practice in different manufactures, and what further investigation was needed next; and he offers the following remarks (though with considerable diffidence) in the hope that, though they reveal no new facts, they may be of interest and of some good, if only in showing up some of our deficiencies and limitations. The subject is one in which for years he has always taken the greatest interest, and striven to study impartially; he therefore trusts that, although associated with steel manufacture, he will not be regarded as speaking from a maker's point of view; he is only wishful that the available knowledge may be turned to practical account.

Steelmakers have, perhaps, to consider these questions more, only because, if any trouble does occur with the steel before it is finished, it is almost always referred to them.

But where can steel users, wishing to avail themselves of the existing knowledge on the effect that treatment has on steel, find the principles succinctly stated and clearly connected with their application in practice? The literature on the subject is confined to papers, which appear scattered over the proceedings of the different societies, the information often being expressed only in scientific terms, and not clearly pushed to a practical issue. Hence the subject is not forced on the notice of men too busy to study and collect all these, and they do not connect them with or apply them to their own practice.

The objects of this paper are, therefore:

1. To help those who handle steel by describing in simple, practical terms such fixed principles as are known up to date, and in what direction they may be applied in practice.

2. To obtain discussion on and information concerning:

(*a*) Various trade processes, and

(*b*) The limitations of the control which maker and user respectively possess over the properties developed by material.

3. To formulate certain views in order to obtain an expression

of opinion upon them, in the hope that such as are publicly endorsed by this Institute may be henceforward regarded as a standard for makers and users alike to refer to. At present, each one sets up his own standard, viz: exigencies of trade.

The views referred to are:

(*a*) As to the degree of responsibility of maker and user respectively for normal results obtained; together with a classified list of the indications that shall be accepted as determining their source.

(*b*) As to certain tests which material ought and ought not to be reasonably expected to stand after given treatment.

The writer, though endeavoring to show by specific instances how, to the best of his belief, the principles may be applied or how certain effects have been brought about in practice, does not intend to imply dogmatically that any given procedure will always produce the same results; each particular case must be considered in conjunction with all the conditions, and these cannot always be maintained constant; so that, though nominally the same, what occurs one time may not another. Even if the suggestions made are in some cases impracticable or incorrect, provided they serve as a starting point, and give rise to discussion, some good should result.

In describing temperatures, the writer fears he will have to risk being considered old-fashioned, and bringing down censure on himself from those who advocate exact temperature as measured by a pyrometer, for not discarding such "obsolete terms" as "dull red," "cherry red," "yellow heat," &c."* Practical men whose eyes are trained by experience know what appearance these give in varying light, such as sunshine, or at night, and can gauge them quite as nearly as the temperatures themselves can be regulated.

An ingot furnaceman has to judge the right degree of heating in all sorts of lights, day and night, at all times of the year.

We may know what temperatures we want and what is right when we see it, and yet not know the real temperature in degrees

* When used, they are all referred to as seen in a dull light.

centigrade; as we have no means of pyrometrically measuring the temperature of a bloom in the process of rolling.*

We cannot fix exactly what the finishing temperature should be, either in degrees centigrade or color temperature, for steel of any given carbon; as besides the mass of the section and cooling facilities, the purpose for which wanted, and hence the degree of rolling hardness most suitable, has to be known.

The simplest and the only proper way is to let the men who have to judge the temperature in daily practice try pieces at two or three varying temperatures (which they can recognize for themselves), follow them through, and make simple mechanical tests, and then adopt the temperature that gives the best results.

A good man will quickly be able to keep to the proper temperatures. A man who cannot is not fit for the job, as he could not either with a pyrometer or if told in terms of color.

SECTION II.—THE EFFECT THAT COMPOSITION AND INITIAL TREATMENT HAVE AS COMPARED WITH SUBSEQUENT TREATMENT ON THE ULTIMATE PROPERTIES OF THE STEEL.

A.—*Considered Generally, and with Reference to what is Possible.*

Composition, and all the treatment that an article receives, each have an effect on it at some period, but the influences most powerful in determining its final characteristics are frequently the latter processes, and these may completely outweigh all others.

It has been usual in the past, and still is in many quarters, to consider that the qualities steel possesses are dependent mainly on its composition, so much so that the term "quality" has become almost synonymous with "composition;" but recently it has become more and more apparent that this is not so, and that, except within narrow limits of treatment, composition plays an insignificant part in insuring given qualities.† Selection of

* "Journal of the West of Scotland Institute," January, 1900, No. iv, containing discussion on A. Campion's paper on "The Heat Treatment and Microstructure of Steel." See writer's remarks.

† See the writer's paper on "Brittleness in Soft Steel," "Journal of the Iron and Steel Institute," 1898, No. 1. The same pieces of steel gave various opposite qualities by treatment only.

the most suitable composition may slightly widen the range of treatment that it will bear and yet give the required results, but it is not possible to produce a steel which is impervious to treatment. The maker controls the initial treatment and the composition, but generally the influence of those is only transmitted a very short distance through the subsequent working-up processes, being completely upset on reheating and rerolling;* thus in ordinary practice a maker can do very little which will materially affect the steel after working up. Thus, unless treatment only had a quite minor effect, say 5 per cent. of the total, or unless the effect of the working-up processes was always definite and fixed and did not vary more than 5 per cent., the maker could not reasonably be held responsible for the subsequent behavior of material, provided it was right when sent out by him.

After it has been further worked, the only way to set an approximately true basis for comparison of the effect of composition in pieces in which it differs is, first, by reheating to redness and letting cool slowly, to remove all hardness which may have been induced by treatment.

As an instance, many years ago, when endeavoring to find whether hard spots in wire were due to local variation in composition (which never was found to an extent exceeding the possible error of analysis), the writer took pieces of $\frac{3}{16}$-inch wire rod of "soft" quality, with carbon 0.10 per cent., manganese 0.40 per cent., hooked them to others of "medium hard" quality, carbon 0.25 per cent., manganese 0.80 per cent.,† and whilst the end of one was held in a vise, twisted the other. Thus, whichever was the mechanically softer was bound to twist more than the other. (See Diagram 1.)

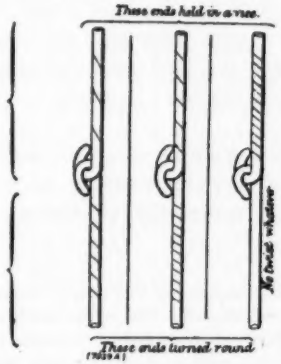
When the basis of treatment in each case was equal, viz: (A), tested in the state as received (with the hardening effect of rolling unremoved), (B) and also after removing the hardening effect by heating as just described, the "medium-hard" wire

* Coarsely crystalline billet on reheating and rolling yielded fine-grained fibrous rods, and fine-grained piece of same billet gave coarse-grained rods according to treatment.

† The other constituents did not differ.

DIAGRAM I.

Effect of Treatment v. *Composition on Twist Tests in Wire.*

"Quality" of steel and composition.	Basis of treatment.		
	Equal. Twisting corresponds with composition.		Unequal. Twisting corresponds with treatment.
	A. Twisted in state received. Hardening effect of rolling not removed.	B. Twisted after hardening. Effect of rolling removed.*	Rolling hardness was in: "soft," not removed (as in "A"). "Medium hard," removed (as in "B").
"Medium hard," Carbon. 0.25 p.c. | Manganese. 0.80 p.c.			
"Soft." Carbon. 0.10 p.c. | Manganese. 0.40 p.c.			

The difference in twisting between two members of a pair is a measure of the effect of the difference in composition.

*Required much less force to twist than "A," and gave many more twists before breaking.

showed, as would be expected, less twist than the "soft" wire (about half). But a piece of the "soft" wire with the hardening effect of rolling unremoved (as in A) would twist the chemically harder wire from which the hardening effect of rolling had been removed (as in B) through a number of turns, without being itself in the least twisted. That is to say, rolling had imparted greater hardness to the "soft" wire than an extra 0.15 per cent. of carbon and 0.40 per cent. of manganese, without the hardening effect of rolling, could impart to the "harder" wire, though

it contained altogether double the percentage of hardening bodies that the "soft" wire did.

In the paper on "Brittleness in Soft Steel," read before this Institution in May, 1898, the writer has also described a number of instances where extreme brittleness, practically beyond the bounds of composition for workable steel, and such as even 1½ per cent. to 2 per cent. of carbon could not impart to unhardened steel, was induced in steel of eight makes, some exceptionally pure and soft, by treatment only. Indeed, extremes of brittleness in soft steel (such as a bar breaking when falling a few feet on a plated floor) can only be produced by treatment.*

There is now ample and conclusive evidence, both from the numerous instances which come under the personal notice of most men having experience with steel, and also published, of—

(*a*) The purest and best steel failing when subjected to unsuitable treatment, such as it might meet with in ordinary processes.†

(*b*) Steel which, from its composition, would generally be considered bad and impure, standing all prescribed tests and requirements of practice, the treatment evidently having been right.‡

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* Yet such a thing happening to a single bar would probably result in the whole lot being condemned. The sooner such brittleness is recognized as being solely the result of treatment by the user, the sooner is there a chance of his looking into his own working, locating cause, and thus stopping it.

† Stead's paper, "Brittleness in Soft Steel Produced by Annealing," "Journal of the Iron and Steel Institute," 1898, No. II; Ridsdale's paper, "Brittleness in Soft Steel," "Journal of the Iron and Steel Institute," 1898, No. I; "Practical Microscopic Analysis," "Journal of the Iron and Steel Institute," 1899, No. II; Cycle crank which failed, mentioned in present paper; Hunt, in his paper before the American Institute of Mining Engineers (see "Iron and Coal Trades Review," June 7, page 1885,) quotes American works which find rails give too soft tests because finished too hot. He also states that chemical composition is secondary to physical treatment—mechanical tests of plates, rails, &c.—which gives tests contrary to what would be expected from their analysis.

‡ In the report made in 1900 by the Rails Commission appointed by the Board of Trade, most exhaustive investigations of all kinds with rails which had been in long actual service, some pure and some containing large amounts of impurities, viz:

As further illustrating the question of purity, other countries regularly produce a great deal of steel which is more impure and varies between wider limits than English makers dare supply; but here the users often do not know its composition, and unless treatment causes trouble, it goes through all right, the same as purer steel.

American steel often runs up to 0.10 per cent. and even 0.12 per cent. of phosphorus, and if of "acid" make, to 0.10 per cent. or more of sulphur, whilst the carbon in soft steel often runs up to 0.15 per cent. or over. An instance was met with quite recently of American "soft" steel containing carbon 0.34 per cent.; phosphorus, 0.08 per cent.; manganese, 0.58 per cent.; being used indiscriminately with British soft steel not exceeding 0.10 per cent. carbon and 0.52 per cent. manganese. This is not the only similar instance that has come under the writer's notice.

German steel, too, though some of it low in carbon, phosphorus and sulphur; also much of it runs up to 0.1 per cent. and

	From *per cent.*	*To* *per cent.*
Carbon	0.291	0.454
Manganese	0.47	1.14
Silicon	0.041	0.207
Sulphur	0.028	0.094
Phosphorus	0.058	0.105
Slag and oxides	0.046	0.098

—show that on the whole the harder (impurer) were better than the (purer) softer. Dormus, an Austrian railway engineer, in his "Weitere Studien ueber Schienenstahl," "Zeitschrift des Oesterr. Ingenieur und Architekten Vereines," 1898, Nos. 44 to 48, gives comparisons of a portion of the line which had worn very badly, and many of the rails had broken, though they had only been down eleven years and eighty million tons had passed over them, with another portion in which the rails had been in use twenty years, and one hundred and two million tons had passed over them, yet they had worn very slightly, and not a single rail had broken. The bad rails were fairly low in impurities, the phosphorus averaging 0.07 per cent., whilst the good ones contained no less than 0.114 to 0.147 per cent. Andrews, in his paper on "The Wear of Rails in Tunnels," read before the Institution of Civil Engineers, 1900, mentions rails with 0.12 per cent. sulphur which had worn very well, as Stead in the discussion pointed out, better than the average life. Brovot, "Stahl und Eisen," January 15, 1896, gives a number of instances of steel high in phosphorus standing very good mechanical tests.

0.14 per cent. phosphorus, as has been freely admitted to the writer and others in German works.

The tables in the next column give some analyses of soft American and German steels from the records of the writer's laboratory, where most of them were made. They are not selected in any way, but from the date of writing backwards over a period all have been taken without omissions. The foregoing remarks are not an attack on foreign steel, but simply given in illustration of the question at issue.

American.

Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.
per cent.	*per cent.*	*per cent.*	*per cent.*	*per cent.*
0.14*	0.03	0.065	0.13	0.56
0.17*	0.01	0.11	0.05	0.74
0.09†	0.04	1.02	0.13	0.28
0.09†	nil	0.03	0.09	0.37
0.12†	nil	0.12	0.09	0.80
0.07†	nil	0.063	0.15	0.58
0.24	0.02	0.04	0.08	0.58

* These two were being used indiscriminately at one works with English steel containing C 0.09 per cent., Si 0.10 per cent., S 0.08 per cent., P 0.06 per cent., Mn 0.42 per cent. The three analyses were supplied by them.

†All described as "Good."

German.

Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.
per cent.	*per cent.*	*per cent.*	*per cent.*	*per cent.*
0.06	No record.	0.01	0.07	0.32
0.06	"	0.02	0.08	0.37
0.06	"	0.04	0.14	0.43
0.05	"	0.02	0.05	0.20
0.11	"	0.02	0.07	0.32
0.07	"	0.04	0.10	0.32
0.10	"	0.03	0.08	0.40
0.10	"	0.02	0.11	0.40
0.09	"	0.01	0.08	0.58
0.10	"	0.01	0.09	0.60
0.11	"	0.02	0.09	0.66
0.08	"	0.02	0.10	0.46

The fact is, far too much importance has been generally attached to composition *per se*, and far too little to right treatment.

Neither trouble nor expense is spared by makers to give the best composition.* In how many works where steel is used is adequate provision made for having the treatment well under command? Would not frequently the least extra trouble (for instance, in turning or stacking bars differently whilst cooling) be considered sufficient reason for the suggestion to be dismissed at once as not practicable? Yet surely every works ought to have provision for complete control, not only of finishing temperatures, to finish higher or lower at will, as required, but also for cooling, so as to cool—(*a*) equally throughout; (*b*) slowly or rapidly.

A difference of two or three hundredths per cent. of carbon or impurity, more or less, is quite insufficient to have any noticeable effect unless the treatment also differs, in which case it would probably have practically the same effect if there were not the slight difference in composition.

B. *Is the ordinary routine of working-up such as to make the best of steel, or is there a tendency to deteriorate it, and sometimes spoil it completely?*

Whilst the heavier articles, such as rails, joists, &c., are generally finished by the steelmaker himself, and he thus controls the treatment right through, in the case of the lighter trades, as has already been intimated, he has little or no control, the steel passing out of his hands through that of at least one, and frequently two or more successive users, each of whom subjects it to some further processes, which soon far outweigh in their effect on the steel the maker's share; and many working-up processes tend to make the steel harder or destroy its "nature" in other ways.

In many cases this treatment is dictated not by how it will affect the material, but by what will give the least possible trouble and cost. Thus it is treated primarily to suit their tools or plant. The men, too, if paid by piecework, give more thought to output than care as to the ultimate condition of the steel. Hence if a

* Both in plant, materials, laboratories, with large staffs, &c.

process (such as annealing), formerly considered necessary, can be omitted or output increased in any way, so long as the cost is reduced, no matter whether the treatment to which the steel must submit is more severe or not, this is done, though the treatment involved to attain this may predispose the steel to fail under sudden shock or continued or accentuated vibration or in some other way. In other cases, where the ultimate character of the material is taken into consideration during manufacture, with the intent to give it every chance, the very means taken to provide against injurious effects may be so carried out as to produce them. Annealing in one or other of its forms is perhaps the most common instance of this.

Again, rolled steel for various sections is every day being introduced where other material* was used before, and the consumers themselves may not always know exactly what they want. Then there are still works where for the most part wrought iron is rolled, and which only occasionally use steel as a small proportion of the whole. In such cases, where furnaces, reheating temperatures, drafting, and strength of rolls, &c., are adapted for iron, there is a strong probability of steel being heated to a higher temperature than it requires on its own account.

Again, the same steel is frequently used for quite different purposes which may require opposite characteristics.

Considering how much steel does not get the best treatment, the wonder is, not that there should occasionally be complaints, but that there are so few, especially in cases in which every inch or so is treated separately, and rejected for the slightest defect. Yet it is usual for the steel to receive the blame, and the maker be left to clear himself if he can, instead of the users looking for the fault in their own treatment. The men, especially if paid on output, will not admit that the treatment has varied, and if the maker suggests that this has been so, he is asked to show in detail how this can be. Therefore the maker, rather than offend his customer, often accepts as his fault what he really does not believe to be his. In most instances, when trouble arises, it af-

* Cast iron, cast steel, malleable castings, wrought iron, &c.

fects only a small proportion of the whole—say, occasional bars, and not a whole cast of ten tons or upwards.

Though generally regarded as indicating irregularity of the steel, this very fact points far more strongly to irregular treatment due to exceptional causes. Composition does not vary materially between one part of a cast and another, except what occurs from the outside of a piece inwards due to segregation, whilst any variation due to treatment by the maker does not count, as it is obliterated on reheating by the user.

Sometimes samples are analyzed, and if impurity is found, one or two hundredths above 0.06 per cent., or the carbon varying to the same extent from specification, that is regarded as the explanation. Purity is a good thing, but men whose knowledge is more academical than practical, are apt to go too far; and to pronounce all steel unfit for use for ordinary purposes which contains more than a total of 0.01 or 0.02 per cent. of any impurity is misleading.

The idea that the user's treatment is the cause of any unusual behavior in the steel seldom occurs to him, and if he says he "does not care what the composition is so long as it gives good practical results," he means that since the analysis is good, the cause must be due in some other way to the maker.

If a maker has made steel really bad in any way, the fault manifests itself in his work, and if it does not do so, it is good enough for most purposes.

SECTION III.

Can the maker do more than at present? And, on the other hand, is it worth the user's while troubling to go into this matter, and study the character of each steel to see what he can do?

As a rule, if a manufacturer knows exactly what processes the steel will have to go through, he can supply a quality which will successfully endure more severe treatment than would be necessary if its nature received due consideration. But frequently he does not know this, whilst sometimes any information on the

subject is jealously guarded. Thus steel, though quite pure, may easily be supplied of unsuitable composition.

As regards composition, it is by no means certain that a still further reduction of the already small quantities of silicon, sulphur and phosphorus usually met with would for most purposes be attended with corresponding advantages; and for the present, at any rate, it is simpler and cheaper to work to limits of up to 0.08 per cent. for each impurity than to only 0.05 per cent. or 0.06 per cent., greater purity meaning greater expense.

All processes in general use seldom exceed the former, whilst the latter means more care in the selection of materials and throughout, so that, broadly, greater purity means greater cost. The writer wishes it to be distinctly understood that he is not seeking in the least to advocate impure steel. Makers are constantly trying by all practical means to obtain greater purity and soundness, and for their own sakes not to sail as near the limit as they can in order to minimize the quantity thrown out, since no self-respecting maker knowingly sends bad material away. The tendency, therefore, is towards greater purity, and meanwhile it would be wise to take the means that do exist to improve its qualities. As a whole, the steel that is marketed is really very good material, and regularly bears treatment and stands tests such as, to the best of the writer's belief, would not have been thought possible (unless with rare exceptions) say twenty years ago, and which ordinary iron will not stand;* and if a quality suited to the requirements were always selected and treated more in harmony with its nature, still better results would be obtained.

Even where, for convenience in keeping stocks, one quality of steel is used for as many different purposes as possible, greater attention to right treatment will often save much trouble, and thus practically give more latitude. It is from want of attention to treatment that such anomalies are sometimes met with as that a maker's steel rolled by one user suits a second, but rolled by

*Such faults as seaminess or lamination, or deficiencies in bend test which would condemn steel, are cheerfully looked over or not regarded as faults in iron.

another user does not, or rolled by a user suits one of his customers but not another. Equally it is no doubt owing to the distinctive characteristics of material being determined mainly by its treatment that such occurrences (as one occasionally hears of) are possible as soft steel being sold as Swedish charcoal iron, and Bessemer steel as crucible steel, and giving the purchasers satisfaction.

On the other hand, no matter whose fault it is, when steel is once spoiled it is vexatious, and may lead to strained relations between friends. No one likes to have wasters or to make complaints, and it is to be hoped that many may be willing to look carefully into their own processes and treatment, and see if there is anything in them which can be modified to the advantage of the steel.

Ever with our present knowledge of the laws affecting steel, there is in many cases ready to hand a means of vastly improving its ultimate quality, greater than could be hoped for in the direction of composition.

It should not be forgotten, when dealing with steels of different makes or types, that every steel usually has a character of its own (much as other metals, such as aluminum or copper), and though 0.02 or 0.03 per cent. variation may not matter if the treatment is not trying, the more so the nature of the necessary process is, the more important is it that this character should be studied, and the treatment should be discriminative, being in harmony with the nature of the steel, if the best results are to be obtained.

For instance, a steel with

C.	Si.	S.	P.	Mn.
0.09	nil	0.05	0.06	0.50

will be softer and require less heat than one by another process with

C.	Si.	S.	P.	Mn.
0.15	0.06	0.06	0.06	0.45

Hence, to argue that because one stands a certain treatment and the other does not the latter is unsuitable or at fault, is not fair.

Whichever the treatment is adapted to, the other will show to disadvantage.

The right treatment may be just as easy as the wrong; and since the steel industries have an unceasingly hard struggle, and all that affects their welfare becomes a matter of national importance, surely every known means should be used to insure that the steel now available shall be used so as to give the very best results.

SECTION IV.

The condition of steel, and how it is affected by work at different temperatures.

As a guide to the application of the principles to details of practice in instances other than those shown later on (which are also based on them), and so that we may clearly understand them in their practical bearing, let us follow the main changes which take place in steel, and how they affect its properties whilst it passes from the molten state until it becomes solid and cold, and *vice versa;* and, avoiding as far as possible the use of scientific terms (and perhaps at the risk of strict accuracy), endeavor to convey the general idea of what for all practical purposes appears to happen.*

THE COOLING OF STEEL.

Molten to Critical Point.—When molten steel cools it crystallizes, the pure iron "grains"† settling out, and the more quietly and slowly it cools, the larger they are. The last part to set con-

*In endeavoring to present a fairly continuous outline, which shall embody such principles having a direct bearing on practice as are necessary for comprehending the various conditions produced, the writer has availed himself of such statements by a large number of authorities as appear to best explain them. To quote each one would require too many footnotes. Whilst it must be clearly understood that some of the explanations must necessarily be hypothetical, they are probably substantially correct. The terms "grain" and "cement," being simple and convenient, are used here, but only in a general sense, without reference to any controversial views. "Cement" must not be confounded with cement carbon, Fe_3C.

† Which are of such form, when uninterfered with, as will pack very closely together and require very little binding medium.

tains more of the carbon and impurities, and may be termed the "cement" which binds the grains together.

If disturbed just as the grains are formed, this cement is still so liquid or soft that they have little or no cohesion, and the material is quite "rotten" or red-short in the extreme.* At a little lower temperature it becomes cohesive and freely plastic, and it can therefore be readily worked, the cement being so soft that the grains, though cohering enough to permit this, are not held rigidly in their relative positions, but are able to move about each other so easily that they are not themselves appreciably broken up; and if work is stopped whilst at this temperature, especially if the cooling is slow, the grain is found to be very large and coarse.

In fact, at this temperature the size and shape of the grain is not affected by work, only by the interference and other conditions of cooling, and the piece exhibits no flow lines and has no rolling hardness. The larger the grain, however, the less coherent it is (owing to the larger area of the cleavage planes) if subjected to sudden shock; so the piece is wanting in toughness, and may be actually "rotten."

Critical Point.—The point of equal hardness of grain and cement, at or below which change of shape of the mass (by work) begins to affect appreciably the size and shape of the grain.

As the temperature descends, a point is reached at which the cement is approximately no softer than the grains, so they will not so readily move about or flow in it; and when the work applied is sufficiently strong, all yields together, and the grain is broken up or elongated, kneaded, and interlocked, and the material thus becomes tougher, being dovetailed as well as stuck together. Flow lines become distinct, and rolling hardness begins to be imparted, these effects being less marked if the cooling is slow.

This has been termed the "critical point,"† and is probably

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*Notice how easily, for a second or so after they are made, splashes of steel can be broken up by a bar; but immediately afterwards it becomes very tough and difficult to tear apart.

†Tchernoff, Brinell, &c.

for soft steel about 1000 degrees centigrade, say orange or bright red, and lower for higher carbon steel.*

Below this point to low red the grain becomes finer and more interlocked, and hence to a certain point the lower the temperature to which it is continued the more work increases toughness of material. At the same time, as the temperature decreases the stiffer the binding medium becomes, and the more strongly the grains adhere; and consequently the more they are "broken up" in working, and the more power it takes to make them flow, the lines of flow becoming more clearly defined, and the mass in parts being already stretched or under tension by the unequal strains set up by the distortion of working, is harder or stiffer.

The higher the temperature below the critical point described, at which work on the piece is finished, not only are the strains set up by working less in the first place, but the longer time it will take to cool; and whether from this, or from its large mass, or any other cause, if its cooling is retarded the strains set up gradually distribute themselves, and are correspondingly diminished or eliminated, and the final "rolling hardness" is therefore less. If the finishing temperature is lower, this softening effect is, of course, less. Thus to a certain point the hotter the finishing temperature the softer the material, though not necessarily tougher; for if the grain is too large, there will be want of toughness. The ideal finishing point is clearly, therefore, that at which these two opposite tendencies are properly balanced.

Below Red Heat.—As work is continued, the relative plasticity of the cementing material to that of the grains becomes rapidly less, until it reaches at

Blue Heat, the State of Minimum Plasticity.—Approximately 316 degrees to 371 degrees centigrade. The grains adhere so strongly, that if force is applied to change the shape of the material (whether by work or by the effects of violent expansion or contraction through sudden or local chilling), it does not uni-

* There appears to be at present no ready means for actually measuring the temperature in degrees centigrade. It cannot be done pyrometrically, because a couple cannot be inserted in the piece at the moment of ceasing work. Therefore, the eye is the only means of gauging the temperature.

formly penetrate the mass; internal strains, more or less nearly equal to the extent of its endurance, and which may be termed incipient rupture, are set up,* and actual rupture between or in many of the grains† frequently occurs, those nearest the furnace being sometimes partially detached or loosened.

Thus, although strain applied slowly will often, by forcing parts to stretch which had not previously done so to the full extent of their elastic limit, afford relief and allow the material to bend without rupture, there is always a predisposition for the mass to break under sudden stress or vibration. The temperature, too, from which the piece has to cool is so low that there is little or no opportunity for these strains to be distributed and thus relieved.

Chilling, of course, in all cases accentuates the strains or rolling hardness,‡ but in the case of a piece of steel chilled from near critical point, the initial strains set up by work have been so slight that, though chilling fixes them, the total hardening effect is for soft steel far less than in the case of steel first worked down to a much lower temperature,§ even if slowly cooled afterwards.

Below Blue Heat.—After the temperature of working gets below straw heat (250 degrees centigrade), and until it is really cold, *i. e.*, at atmospheric temperature, say 15 degrees centigrade, steel is more plastic than at a blue heat, though still affected in much the same way if work is sufficiently strong. At still lower temperatures, say below freezing-point, it becomes harder again.

From the foregoing we see that toughness depends on cohe-

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* Just as with a piece of thick, hot glass or slag suddenly cooled.

† Such parts as had been strained or stretched to the extent of their elastic limit.

‡ Both by fixing the strains and setting up new ones due to sudden contraction.

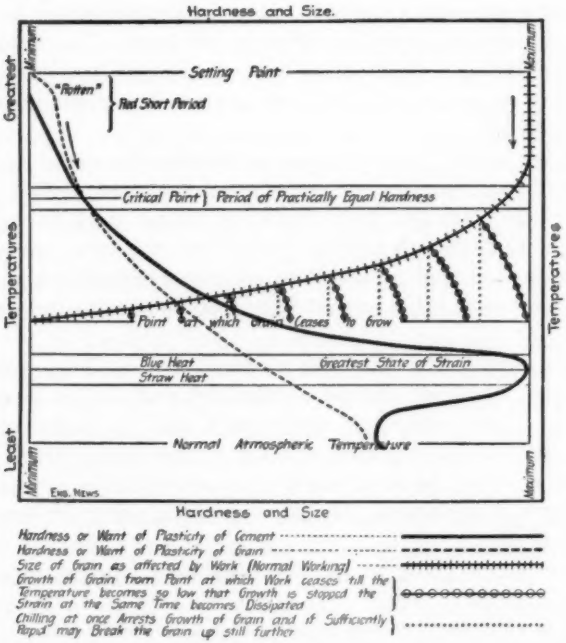
§ On several occasions pieces of slab rendered so brittle by rolling too cold or chilling at blue heat that they broke off very brittle when cold sheared, on reheating to cherry redness and chilling in water sheared quite soft; and a plate rolled from such a piece was also quite soft, and stood the most severe bending tests.

DIAGRAM II.*

The behavior of steel at different temperatures would seem to suggest the occurrence of the following:

CHANGES IN THE "GRAIN" AND "CEMENT" WHILST COOLING.

This diagram is not intended as a measure of the changes, but simply to indicate their directions.


Hardness and Size.
Greatest
Minimum
Maximum
Setting Point
"Rotten"
Red Short Period
Critical Point
Period of Practically Equal Hardness
Temperatures
Point at which Grain Ceases to Grow
Blue Heat
Straw Heat
Greatest State of Strain
Least
Normal Atmospheric Temperature
Eng. News.
Hardness and Size
Hardness or Want of Plasticity of Cement
Hardness or Want of Plasticity of Grain
Size of Grain as affected by Work (Normal Working)
Growth of Grain from Point at which Work ceases till the Temperature becomes so low that Growth is stopped the Strain at the Same Time becomes Dissipated
Chilling at once Arrests Growth of Grain and if Sufficiently Rapid may Break the Grain up still further

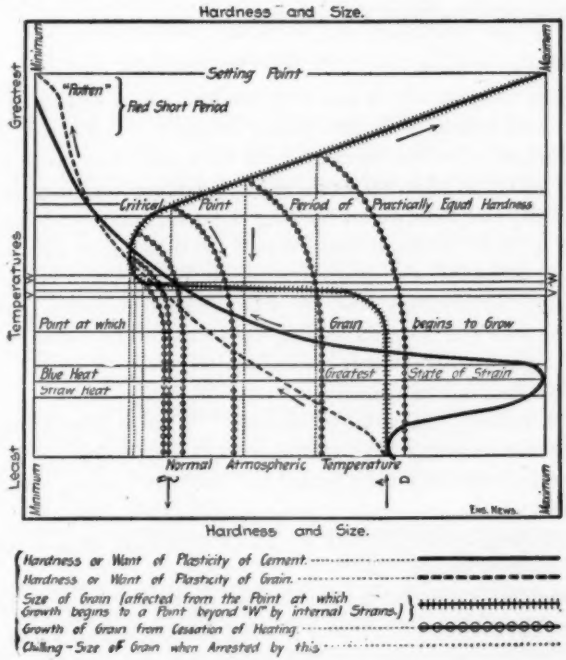
* From this diagram, and also Diagram III, it will be clear how the time element acts, since if the "line of growth," even from one of the low temperatures, be continued far enough, it will reach a point as high as that from one of the higher temperatures arrested sooner.

† For clearness these lines have not been carried beyond the line indicating the point at which grain ceases to grow. From this they would, of course, continue parallel with the maximum and minimum lines to the line indicating normal atmospheric temperature.

DIAGRAM III.

The behavior of steel at different temperatures would seem to suggest the occurrence of the following:

CHANGES IN THE "GRAIN" AND "CEMENT" WHILST REHEATING.



The size of grain at commencement of reheating is.....shown at A.

Reheating only to W gives the finest grain obtainable with slow cooling.....} shown at B.

Reheating a little (say 100 degrees centigrade) above W, by allowing more re-growth, gives a slightly larger grain.....} shown at C.

If reheated to a sufficiently high temperature, the grain has grown again so much as to be larger than before reheating.....} shown at D.

sion of the grain, and the greater this is the greater the toughness. Want of cohesion at or near the setting point, or at any temperature down to red heat, is termed "Red-shortness." Want of cohesion when cold (atmospheric temperature) is "Cold-shortness." Softness is readiness of the grain to change its relative position, and hardness the reverse.

REHEATING.

When material which has been worked below critical temperature, and hence is distorted and strained, is reheated, as the temperature rises the reverse effects take place to a large extent, there being no external work. After passing above blue heat, the grains and the cement holding them together get softer, and begin to yield* to the internal strains till they adjust themselves; and so, although the mass retains its new shape, its internal structure is rearranged, and the strains redistributed or removed, and the material loses its rolling hardness and becomes soft and tough again. This is true annealing.†

Annealing has two actions:

1. Removing the rolling hardness. This is done whether it is heated to a pretty high temperature, say 950 degrees or 1,000 degrees, as well as if only heated to "W," say 730 degrees to 800 degrees.

2. Making it fine-grained, for which reheating should only be to or slightly above "W."

Just, however, as the cement in cooling below red heat became harder than the grains, so in reheating correspondingly; at these temperatures the grains are still softer; and hence if the heating is rapid the grains soften more quickly than the cement, and it is they which yield to the internal strains (already existing, and also set up by rapid heating) and become pulled asunder, or out of their more or less regular shape into new and more interlock-

*The point at which this takes place at all rapidly has been termed "V" by Brinell, but, as pointed out later, it has been proved that, given sufficient time, it begins sooner.

† Of course, this treatment will not remove actual rupture which has already taken place, though, no doubt, further work at a high temperature would cause it to weld up.

ing shapes, and are thus "broken up." This even applies to the large grains of material finished too hot, and is particularly important because material predisposed to be brittle, from either being finished at too high or too low temperatures, regains its good qualities if rapidly reheated. If the heating is more gradual the strains operate less violently; and, though the softening effects are to some extent obtained, the "breaking up" is less marked. Hence the importance of the heating being rapid to obtain the maximum softening effect.

When the temperature rises above critical point again, the cement becoming softer than the grains, they follow the natural law of attraction and tend to aggregate into larger grains with thicker intervening bands of cement, just the same as before the material had received sufficient work at a temperature below critical point; the higher the temperature the more this is so, and the slower the cooling the more it is visible when cold. The same law is always ready to come into operation even at lower temperatures, but at or near blue heat the cement is so stiff and offers so much resistance that it is unable to do so, although at temperatures considerably below the critical point*—the lower reds—provided the time is sufficiently long, a similar result is obtained. Annealing may, in either of the above ways, be carried too far so as to be injurious.

Fatigue and restoration by rest come under this category, as they are a continuation of the law at still lower temperatures; but as these are not strictly "treatment," they are not discussed here. The converse fracture by vibration and alleged growth of grain, and consequent brittleness or loss of nature (strain or incipient rupture), might be considered "treatment," as being a contributory cause to faults developed; probably when this occurs the coarse grain was already existent, and rupture only ensued from vibration causing cracks to develop.

When the temperature rises considerably above critical point, and approaches setting or melting point, the cement again

*Stead has traced it down to (low red) 600 degrees centigrade to 750 degrees centigrade, 48 hours. "Brittleness in Soft Steel Produced by Annealing," pages 9 and 33.

becomes too soft to hold the grains firmly; and their coherency becoming less, the stage of "red-shortness" is once more reached. Thus we see one reason why overheating produces "red-shortness." Another is the burning out of the carbon from the carbide of iron in the small quantity of cement; thus it loses its nature and ceases to act as such; or, if carried too far, not only may the carbon have been burned out, but there may be even substituted a film of oxide which reduces cohesion still further. It is easy to understand from the above how the presence of a little carbon, say 0.1 per cent. to 0.15 per cent. (or similarly of manganese, silicon, and possibly even phosphorus) enables the steel to stand more fire (*i. e.*, heating for a longer time or to a higher heat, provided it is below the temperature of red-shortness) without exhibiting want of cohesion during or after working from this cause; this quantity taking longer to burn out than, say, 0.05 per cent., to 0.07 per cent.; but at the same time, if it gets higher than this there is so much more cement that it becomes soft too readily, and the grain is too much cushioned, and does not get worked enough; hence higher carbon steel requires to be worked at a lower temperature for the grain to be sufficiently acted on, and at lower temperatures strains are more readily set up. Similarly, steels with little or no carbon (like iron) have so little cement that they do not lose their coherency at a temperature at which higher carbon steels with more cement would, and hence will bear a higher working temperature without falling to pieces, though they are better without it, unless wanted very soft.

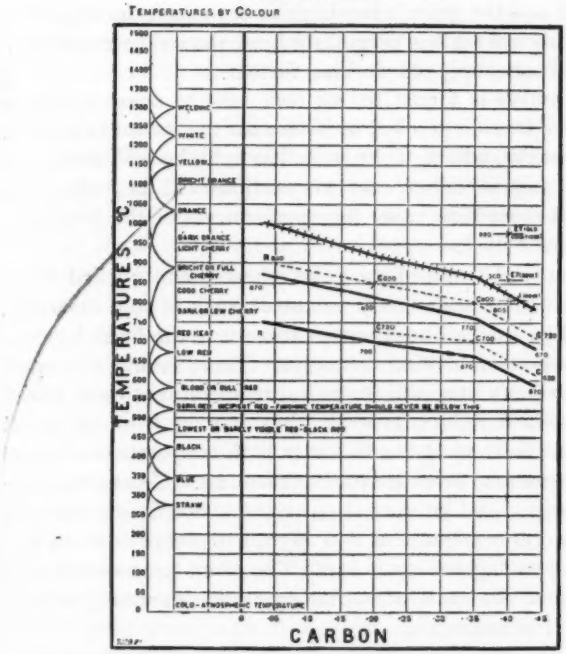
SECTION V.—SAMPLES OF PROCESSES AND TREATMENT STEEL HAS TO UNDERGO IN PRESENT PRACTICE, WITH SUCH MODIFICATIONS AS SCIENTIFIC PRINCIPLES SEEM TO SUGGEST.

ROLLING INGOTS.

Treatment by the maker till it leaves his hands.

(*a*) For steel which is going to be reheated and worked further exactly as it is sent away, without undergoing any preliminary process, the limits of the temperature at which work is finished are not set by, and are immaterial so far as their effect on its

DIAGRAM IV.



Campion's* limits for best results for carbon — 0.44 per cent. to 0.20 per cent. for reheating (= "W") marked ..... C } Connecting line.

Ridsdale's† limit for best results for carbon — 0.16 per cent. to 0.03 per cent. for continuing work down to marked ..... R } Connecting line.

If, as per Howe‡, 30 degrees is deducted (from Campion's figures) to give temperature to continue work down to *i. e.* for material cooling (= "V").

The best finishing temperature may be higher or lower according to mass, &c., and not always within these limits.

Thus the finishing temperature given by Hunt§ for 80 pounds rail at Edgar-Thompson are marked ..... E T

The finishing temperature given by Hunt for rails at Joliet are marked ..... J

The critical temperatures (at which grain begins to be appreciably affected by work) will be above the top limit of the "best" temperatures, and if it corresponds with them will probably follow the line ++++++++++++++++++

* "Journal of the West of Scotland Institute," January, 1901, "Some Experiments on the Annealing of Steel."

† Discussion of Campion's paper, "Best Temperature for Reheating of Steel," 0.03 to .16 per cent., C., 900 degrees centigrade. Discussion of Stead's paper on "Brittleness in Soft Steel Produced by Annealing," "Journal of the Iron and Steel Institute," 1898, No. II, "Best Temperatures for Working Down to Lower Limit," 750 degrees centigrade.

‡ Harbord and Twynam, "Journal of the West of Scotland Institute," No. VI, March, 1898.

§ "Iron and Coal Trades' Review," June 7, 1901, page 1185.

ultimate properties are concerned, since whether it is finished hot or cold and the grain is too large or too small, the respective effects of this will (as has previously been shown) be completely removed on reheating and working further.

But the maker is forced for his own sake to observe certain limits; for if he rolls too hot or before his ingots are set, he will make defectives, whilst if he rolls too cold he will strain his machinery, and in either case his sections will be wrong, and these limits more than cover the requirements of the properties of the finished steel.

(*b*) If the steel is not going to be reheated and worked till it has received some preliminary treatment (such as cold shearing), or if it will be used without further treatment, the finishing temperature and rate of cooling do matter. There should, of course, be sufficient work at a sufficiently low temperature to well knead the material and reduce its grain, thus making it tough, but it must also be finished at a sufficiently high temperature to avoid inducing brittleness or undue rolling hardness. Unless in exceptional instances, and for special purposes, above bright red 850 degrees to 900 centigrade is too high, and below low red 600 degrees to 700 degrees is too low. The exact temperature must be determined for each particular case and according to tests required. For example:

RAILS.

So long as these meet the specified tests without difficulty, it may not be thought worth while taking any steps to follow exact scientific principles, even though the quality of the material would be rendered still better thereby. Medium heavy sections generally finish within the right limits and meet the tests easily, but it sometimes happens, with the two extreme weights, they are not so readily met.

Heavy Sections, particularly double-head and bull-head, 90 pounds to 100 pounds.—The tendency is to finish at too high a temperature and get too large a grain, especially as they are hard (carbon, 0.35 per cent. to 0.50 per cent.) and pack on the bank into a close, solid mass, and thus cool slowly. They may be quite soft

to dead load, but wanting in toughness under ball test on account of this large grain.

When they cannot be rolled cool enough (say low red), they might perhaps be air-cooled more rapidly, by spreading or other means.

Light Sections, particularly flange rails, 35 pounds to 50 pounds.—The tendency is to finish at too low a temperature, especially for the flanges. This is the more so as they do not pack so solidly together. They may be very rigid under dead load and show too hard, or be wanting in toughness under ball test, owing to the thin parts being rolled too cold, and the strain set up by the unequal finishing temperature and rate of cooling. If they can be finished hotter, say the heads "good" or cherry-red, or by any means massed more, and the surplus heat from the head made to retard the cooling of the flange, such as standing them alternately on their flanges and heads, this ought to be beneficial.

An arrangement of this nature is adopted at Homestead on the intermediate cooling bench, and is being introduced at other American works (Fig. 5).

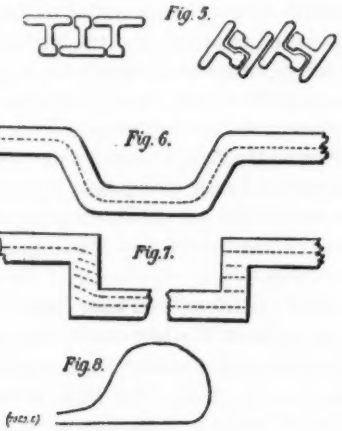
Girders and other "Sections."—These being used for structural purposes or without further treatment than drilling, the finishing temperature and cooling may usually be regulated, mainly with reference to giving the right tests, so long as the extremes mentioned in the general directions are avoided. This will generally be from "low" to bright cherry-red.

Plates.—Much the same may be said of these, but they may receive treatment which will develop brittleness that it will probably be out of the power of the maker to anticipate and counteract. As these may have to be sheared, note next paragraph.

Bars which have to be Cold Sheared before Reheating.—As these should cut soft, it is very important, especially the larger the mass, that they should be finished at a good cherry to bright-red (say 800 degrees to 900 degrees centigrade), well above anything like blue heat, and cooled slowly, and should not be in any way chilled, especially at or near blue heat, either entirely

or locally. Even chilling right out from red-hot would not have half so injurious an effect.

Any chilling of a mass by which a part is chilled for some time may be particularly detrimental, as the hotter parts may maintain the part being chilled at a blue heat all the time the mass is cooling, and the strains be intensified thereby. As an instance, on a wet day, a leaky roof letting water trickle on to a bar or plate all the time it is cooling, or chilling with a



hose if in haste to load the material, may set up very great strains. Cooling strains are well recognized in castings, and great attention is paid to proper stripping, &c. However, even should the bar cut brittle through finishing too hot or too cold, or through chilling, the harm ends here, as once it is reheated and reworked, all injurious effects will be completely removed.

The top and bottom limits of temperature between which work should be finished are shown approximately on Diagram IV.

It should be borne in mind that the larger the mass the less work it will have received (besides being hotter inside than it appears to be), and hence the larger its grain and the more slowly it will cool; so it should be finished cooler than a smaller mass,

which will cool more rapidly, or else the large sections should be spread out and cooled more rapidly, and small sections massed and cooled more slowly.

TREATMENT BY THE USER.

Rolling after Reheating.

The main points to observe are:

1. Reheat as rapidly as possible consistent with the mass, in order to break up the grain. Gradual heating does not do this so effectually.

Masses, such as ingots or blooms large enough to crack by very sudden heating, must, of course, be heated more cautiously, and also require proportionately more time and must have—

2. *Sufficient Time to Heat all Through*, otherwise work will cause unequal extension and lead to internal tearing or separation (lamination and so-called "hollowness") of the mass. At the same time do not soak, *i. e.*, leave in the furnace, any longer than is just necessary to heat all through; two to three hours at "harmless" temperature (and perhaps less, according to mass of piece and temperature of furnace) is quite enough to make the piece very coarsely crystalline,* and this, if rolled quickly, so as to finish hot, and cooled slowly, may easily give a product which has coarse grains and is more or less brittle or "rotten." Remember that if there is delay (from breakdown or other cause), damping down till ready for work will (by allowing very gradual cooling) permit and not prevent growth of grain.

The best plan is to draw the blooms, &c., and spread them so that they cool rapidly, then later, when reheating, the grain will again be broken up. Failing this, when they are worked, finish them rather cooler than usual, to reduce the grain more (but not below red or blue heat), and spread out so as to cool rapidly. This is somewhat risky, however, as, if the grain has already grown large, and the steel is worked to at all too low a temperature so that strains are set up, it will be still more brittle.

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*Ridsdale, "Brittleness in Soft Steel," "Journal of the Iron and Steel Institute," 1898, No. 1.

The best and only certain course to determine the most suitable temperatures for finishing is for each user to make actual experiments with the various sizes he rolls, so that when such circumstances arise he may know exactly what to do. It is very little trouble to try a few short pieces of the same bar at different finishing temperatures and rates of cooling, and make mechanical bending tests, &c., on these. The best test, when the pieces are not too large, is the shock test on a V-block—no nicking; nicks are not uniformly deep—whilst slow bending or tensile tests do not always show up the changes.

3. *Do not Burn*, if using hot furnace, or with thin goods, such as merchant "iron," small sections with a lot of work on them, &c. There is more likelihood of this when rolled into thin deep I or ⌊⌋ sections, and the pieces are rolled very hot. It may seem superfluous to give this caution, but instances are sometimes met with where only one edge out of two or more (and this perhaps only in parts) is cracked, the others being quite sound, and yet the steel is blamed.

4. *Do not Over-anneal*, if the product is to be annealed. If it is of large mass, &c., unless it has received plenty of work and been finished at fairly low temperature, say, low red (600 degrees to 700 degrees centigrade), do not put whilst still hot, in a pit in the ground, or in an annealing furnace, or even stack in large heaps, lest the very slow cooling may cause the grain to grow. This would do good to small sizes finished at low temperature (dull red or lower); but by far the best annealing is to let the steel get cold first and then reheat rapidly to cherry-red for a short time, afterwards let cool again fairly rapidly; do not chill if hard carbon.

THE FORGE.

Forging.—What has been said as to rolling of the temperatures for finishing work as well as of cooling, applies here, though even greater attention is required to these points, since the shapes of the finished forgings are relatively less simple, and thus internal strains may have more serious results.

It is, of course, particularly important that the steel should be

sufficiently plastic for work to thoroughly penetrate the mass and cause the material to flow evenly, otherwise separation of the fiber or "hollowness" may occur in places.

Bear in mind the lines of flow already existing in the piece, as when it is possible to get the required shape without too sudden interruption of these, the forging should be stronger and tougher. For instance, a crankshaft bent gradually so that the lines of flow are also bent round, as in the dotted line (Fig. 6), should be stronger than one in which their direction abrubtly changed, or continuity was interrupted by machining (Fig. 7).

When a whole piece is heated, and only part of it receives work, if the heating is gradual and lasts long (particularly if there is more than one heating, the piece not getting below low red each time), a large grain may be developed, which is not broken up in the unworked parts.

On the other hand, if only part of the piece is heated, as it passes through all gradations to cold, there must be a place where it is at blue heat, and the jar from each blow will reach this part. Thus in the one case the large grain, and in the other the strain set up, may result in fracture, though perhaps not till some time after. Seeing, therefore, that there is a weakness or internal strain in every forging, it is desirable to remove this, and the most effective way is to let it cool and then reheat from the cold as rapidly as possible, consistent with the mass, to cherry-red, taking care that either the whole is reheated or that reheating overlaps all parts which had previously been at a blue heat, or had been reheated whether with or without work.

Even though the area to be so reheated is too great to do all at once, it will suffice to do it in successive portions. Reheating thus conducted will break up the grain, and cooling can take place naturally in the air with no special care to retard it, unless it contains over 0.30 per cent. carbon, or is rendered necessary for some special reason (such as a very irregular distribution of mass). It will be noted that although detrimental effects might arise during forging, when, owing to the entire piece not being heated, there was a part at blue heat, these ill effects would not arise in reheating as above, although there might then also

be a part at blue heat, because in the latter case there would be no work and no vibration to affect such part.

From the foregoing it is obvious that work should never be continued on any part which is below fair to cherry-red (say 800 degrees to 900 degrees centigrade), though sometimes in practice it is continued to or through blue heat to give it a good finish. Any one who has by practical experiment seen what light blows at this temperature will render a comparatively large mass brittle will realize how unwise such treatment is, and how very necessary an annealing by reheating as described, becomes, in cases where work has been continued to these low temperatures.

Drop or Press Forgings.—The numerous small articles which are forced into shape between dies with one or more blows or rapidly applied pressure, whilst the steel from which they are made is, in order that it may be sufficiently soft, at a welding heat, are liable to have a coarse grain and consequent brittleness or "rottenness," because of the high temperature at which the work on them is finished, there being frequently no work below critical temperature. As an instance of this, the writer can cite one of the cranks of a bicycle of well-known good make, which, though of excellently pure composition—

	Per cent.
Carbon,	0.12
Silicon,	Trace.
Phosphorus,	0.04
Manganese,	0.60

broke short off whilst he was riding on level ground, and exhibited a very coarse fracture. There was clearly nothing whatever the matter with the steel itself, but only with the treatment it had received. Had it been rapidly reheated to cherry-red as described, its grain would have become fine, and toughness been restored.

THE BLACKSMITH'S SHOP.

Forgings.—What has been already said as to these applies with as much or greater force here.

Perhaps the practice of "putting a nice finish" on forged

pieces by keeping on hammering them through low red and blue heats is commoner here than in the forge, and needs special attention called to it.

The writer has often seen eye-bolts and other articles which had to bear considerable weight treated in this way, and has also seen numbers of the same when they had "mysteriously" broken.

Welding.—Every blacksmith understands that if he continues to "sizzle" a piece to be welded too long he will burn it, but a great many do not know, or do not act as if they knew, that any part which has been raised for a minute or two to welding temperature, and has not afterwards received sufficient work at a low temperature, has developed a coarse grain, and is probably brittle or "rotten," particularly if the pieces have been cooled very slowly.

This applies to iron as well as steel. Anyone who notices the various fractures that can be seen in any large works, of articles that have been welded—pieces of rods, bolts, links of chains, &c., —will see that a large proportion of them have very coarse grain, the coarseness having probably arisen from this cause. But whether a piece has been worked too hot or too cold, or has not received work after having been at a welding temperature, the cure is as already described—reheating the whole of the parts so affected rapidly from the cold to cherry-red, and then letting cool naturally in air.

Every blacksmith also knows that if he wants to make a good, sound weld—practically as strong as the unwelded part—he must use sand or some other flux to cause the infusible scale or oxide to flow away from between the faces to be welded, and let them unite cleanly.

The writer is aware that in many works and in different processes of manufacture, owing to the excellent nature of soft steel and the great ease with which it welds, a flux is not used, and that notwithstanding this, on the whole, it gives satisfactory welds. For instance, the writer has seen 3-inch by $\frac{3}{4}$-inch bars being simply looped till one part lay on the other, and then welded without any flux at the parts touching each other (Fig. 8). But it is

easy to understand that a very slight increase in the temperature of the piece or the length of time it is exposed to that temperature (and it is not conceivable that these conditions are always quite uniform), may so increase the thickness of the scale or burn the "nature" out of a thin piece that, if it welds at all, the weld is imperfect. If this is the case, the steelmaker is probably told his steel is at fault. However justifiable or desirable for convenience welding without a flux may be, it is not treating the steel in the way to get the best results from it, and the writer cannot think that such welds, as a whole, can be made with equal certainty, or be as reliable when made, as those made in the good old-fashioned and at the same time, scientific way, viz: with a flux, and he would like to have this point discussed fairly and squarely by some one who does not use the flux.

Tubes.—These are generally made from slabs which are first rolled to strip—perhaps at a different works to the tubemaker's. The strip is reheated, bent approximately to the shape of the tube, and the lap formed, after which it is heated for a short time to good welding heat, drawn over the mandrel, and welded without a flux being employed.

None of these preliminary reheatings need be very high, and it is obvious that where material is heated several times and finally subjected, whilst only thin, to a very high temperature, that great care is necessary throughout to avoid burning the nature out of the steel.

The writer has been told by a tubemaker of the highest standing, that the furnaces at his works in which this final heating was received were often at a temperature of 1800 degrees centigrade and that one and a half minutes might be sufficient, whilst two minutes would spoil the steel; also that the temperature was constantly varied at the workmen's discretion, and there were generally several tubes in at once.

Often steel receiving such treatment is not more than $\frac{3}{16}$ inch thick, and the work is done so rapidly as to be finished above critical temperature, resulting in the grain being coarsely crystalline, which is unfavorable for cold expansion tests.

Such conditions, viewed in the light of all we know, seem very

severe, and the writer cannot help thinking that whenever satisfactory results are not obtained, unless analysis shows the steel to be decidedly unsuitable, the cause should be unhesitatingly assigned to the treatment.

The precautions which seem to suggest themselves are: First, great attention to all the heatings to avoid the formation of scale and burning out of carbon from the surfaces to be welded, and unless the objections are insuperable, the use of a flux, as this would admit of less heating and protect the steel; and secondly, that either work should be put on the material after it is below critical temperature (say at low red), or the tubes after cooling rapidly should be rapidly heated to cherry-red for a minute or two and allowed to cool naturally in air.

Gas Cylinders and Other Welded Goods.—The same precautions should be observed as described for tubes, and when only a part of the material is heated to welding, so that another part is at blue heat and may suffer accordingly (as described for forging and welding, the re-heating of those parts as just referred to should be adopted to remove any harmful effects.

Plates.—The treatment these receive which may affect their properties are usually bending, pressing or flanging (hot or cold), punching, shearing or piercing, and welding.

All these may set up more or less severe strains, resulting from work at too low or too high temperature affecting parts only. Flanging by continued hand hammering, either at a blue heat or cold, is particularly trying to the material.

All these strains may be removed by reheating rapidly to cherry redness for a minute or two and allowing to cool naturally in air. When the makers know that plates thin enough to have much rolling hardness must stand any severe work, if they can finish them hotter, say at a good cherry-red (say 800 degrees to 900 degrees centigrade), and let them cool slowly in masses, they would be able to supply them in a somewhat softer condition.

The effect which the finishing temperature and the amount of work have on the hardness and toughness of a plate, and on the tests it will stand, are widely understood and can be largely con-

trolled by regulating them. (See also paragraph on "Tests," Section VI.)

Sheets, Backplates and Tinplates.—Much the same applies to these as to thin plates; being thinner, they tend to be finished colder, which, though often done intentionally to give them a better surface, results in greater rolling hardness. Hence, for many purposes they are "annealed," the treatment generally consisting in packing them in large piles into boxes which are intended to exclude the air from them whilst they are heated (but which are generally cracked and let in quite enough air to burn out a good deal of the carbon from parts at least of the sheets). A strip of varying width round the edges shows airing by its color. These boxes are heated up slowly, which may take from a few hours to a day, according to size, and then maintained from eight to twenty-four hours or more at full red heat and allowed to cool down very slowly, heating and cooling taking altogether from one to three days. This gradual heating and cooling, if carried at all to excess as to temperature or length of time, will undo the good of reheating by promoting the growth of grain*, and if too much air gets in, by burning out the carbon, so that in either case the sheets may be more brittle than before.

The more rapidly it is possible to heat the sheets up, and the less the time they are kept hot once they have reached cherry-red, the smaller the grain and the tougher they will be.

All sheets that are paired or folded two or more times are liable to get foreign matter, such as scale, coal dust, or ash, &c., between them, which may stick to and become imbedded into the plates, and form streaks of various shapes, sizes and color, or, if they afterwards come away, leave the corresponding roughness and indentations on the surfaces. These streaks, if only small and thin, may be removed by the pickling which usually follows, and the roughness obliterated by subsequent operations, such as cold rolling, tinning or galvanizing.

The foreign matter is always present to a greater or less degree, and it is rarely that slight streaks may not be observed on such

* Stead, "Brittleness in Safe Steel produced by Annealing," "Journal of the Iron and Steel Institute," 1898, No. II.

sheets; but when they are rolled a little hotter than usual, so that the surfaces are softer, the dirt sticks and is rolled in more easily, the result being wasters. No streaks of this description are ever the fault of the steelmaker.

The writer was some years ago, afforded the opportunity of investigating this matter thoroughly at several works, and was able to reproduce at will all kinds of typical streaks and indentations, and thus to demonstrate clearly to the complete satisfaction of the principals how they were brought about, and obtain their full admission that this was so.

The matter is also referred to later. (See "Faults," Section VI.)

The chief treatment which sheets may have to undergo are for:

Tinning.	Galvanizing.
1. Rolled.	Rolled.
2. Black pickled and swilled.	Annealed (not always for common sheets).
3. Annealed in boxes as described.	Black pickled and swilled.
4. Cold rolled.	
5. Annealed again, but more lightly.	Galvanized in molten zinc at a temperature of 412 to 500 degrees centigrade.
6. White pickled and swilled.	
7. Tinned.	
Afterwards stamped, pressed, &c.	

Blisters are described under the head of "Pickling."

Strips being simply narrow, thin plates, much the same applies to these as to the latter.

For stamping, shearing, punching, or similar purposes they should be very soft. They are used either in the state as rolled or as cold-rolled bright strip. This latter, though materially hardened and sometimes rendered brittle by the pickling and subsequent cold rolling it has undergone, cannot be annealed after cold rolling, because this would spoil the smooth, bright surface. In either case, that they may be as soft as possible at the outset—if rapid reheating to cherry redness for a minute or two and allowing to cool naturally in air, or an ordinary annealing as for sheets is not practicable—finish rolling at a good cherry red and allow to cool slowly in large heaps.

Strips for Welding into Tubes, or for any purpose in which there is further reheating, should receive as little heating and be rolled at as low a temperature as practicable, since they have in all to stand a lot of fire, and rolling hardness in them does not matter, as it is at once removed by the next heating.

Hoops, being simply smaller strips, come under the same category. There is sometimes a tendency, as they are so thin and cool rapidly whilst rolling, to heat them to a very high initial temperature, and perhaps burn them, causing red-shortness. Again, a good deal of importance may attach to the degree of stiffness they possess and to their color, on the one hand (as in baling hoops), whilst on the other, if they are of 0.2 per cent. to 0.4 per cent. carbon, they may be brittle if rolled at too low a temperature.

A good deal may be done to avoid all the troubles named by rolling at not too high an initial temperature, so as to avoid red-shortness, but cooling slowly in heaps to avoid too great hardness.

Wire Rods and Wire.—Though the area of these is relatively small, wire rods are generally rolled so fast, especially in continuous mills, that they finish at a good red heat; and being wound in compact coils, which are often stacked in large heaps, they cool slowly, and are not so hard as might have been expected.

At the same time, the rolling hardness is considerable, as can be seen from a comparison of the twisting test on wire as it leaves the rolls, and the same after rapidly reheating to cherry-redness and allowing to cool. The hardness is no doubt increased locally wherever the rod touches a cold object, such as a part of the reel, a floor plate or cold coil, or if put outside in wet weather, and may sometimes amount to brittleness.

High-carbon steel is, of course, more affected by all hardening influences than low-carbon steel.

It is not often that wire rods are finished hot enough to render them, even with slow cooling, brittle or "rotten" from this cause, but occasionally in the thicker grades, such as guide rods, three-eighths of an inch in diameter and upwards, instances have been

met with, though it is more than probable there has also been "soaking" of the billets before rolling when this occurs.

Wire Rods for Drawing are usually first pickled, swilled, lime-washed and annealed, and then, after every two or more drawings (according to the reduction, the carbon contained, &c.), re-annealed lightly. There is no doubt, a tendency to draw through as large a number of holes as possible, and minimizing annealing Cold drawing has, of course, a very marked hardening effect, and, if carried a little too far, may easily make the steel brittle.

Wire rods and wire for galvanizing, after pickling, are usually passed through a long red-hot furnace at such a rate that they are not scaled, but just dried and heated up to about the melting-point of zinc before entering the bath. Zinc melts at 412 degrees centigrade (which is just above blue heat), and to avoid loss of zinc it must not get too hot, so that the wire, with its pickling hardness perhaps not completely removed, is for a short time, both before, during and after galvanizing, kept at or near blue heat whilst under tension and vibration.

It is not surprising, therefore, that hardness or brittleness is more frequently met with, especially in guide rods and large sizes, in galvanized than in ungalvanized goods.

Pickling.—It is pretty well recognized, and there is a good deal of published evidence, that pickling causes hardness and brittleness, sometimes to a very marked extent, which is generally attributed to an alloying of hydrogen with iron, and this is no doubt substantially correct.

The writer has several times heated pieces of pickled wire rod of various ages, that were hard, in an atmosphere of carbonic acid contained in a glass tube sealed at one end, and obtained, particularly between barely visible red (say 500 degrees centigrade), and low cherry-red heat, to which the heating was continued, an evolution of gas which (besides the carbonic acid gas used), on testing, proved to be hydrogen.

As soon as this gas was liberated, the sample became quite soft. The writer has never seen conclusively explained why or under just what conditions the hydrogen is absorbed; whether it is a question of strength of acid, temperature or length of time,

but it is quite certain that pickling does not always have the same effect.

Observations could probably be best made in some works where pickling is a regular operation, and it would be very interesting if some one would take this up.

It is also pretty well recognized that pickling may cause blisters on thin sheets. These pickling blisters are quite distinct from ordinary blowhole blisters, and are usually thickly distributed over the plate, and range from about the size of a pinhead to that of a pea. They never appear until after pickling, and often come up during the annealing which follows it. Such blistered sheets are also brittle.

The writer has sheared such blistered sheets into shreds under water, and collected the liberated gas, which consisted essentially of hydrogen, as obtained from the pickled wire rod; whereas blowhole blisters, such as are occasionally met with in the sheets when first rolled, are generally larger (sometimes quite large), occur isolated or in small groups, and consist chiefly of carbonic oxide and nitrogen, no hydrogen.

Pickling blisters, if they only come up after annealing, have lost their hydrogen, it having been expelled by heat and replaced by air. Frequently a small hole is visible in the head of each blister where it has burst and the air entered. As with pickling hardness so with pickling blisters; the writer cannot exactly say what are the conditions under which they are produced. At some works they are recognized as being solely the product of pickling, whilst at others, with exemplary consistency, the steelmaker is blamed for them.

Some years ago, at one of several works where the writer was assured that pickling was solely responsible for them, to prove it about a dozen plates were taken at random from a number of packs (all of which had been pickled in the ordinary course without any blisters appearing), and hung over the side of a pickling vat, so that they dipped half way in, and after a short time the lower halves of the plates were all covered with pickling blisters, the line of demarcation being quite sharp. In this case the extra pickling was the immediate cause.

It seems probable that the grains, which in thin sheets are flattened into flakes or laminæ, become separated, perhaps, by the action of the acid, and, when sufficiently thin, the film of metal is distended by the hydrogen, either at once or by the heat whilst annealing.

From experiments conducted by the writer (though he cannot consider them final), it seems strongly probable that blistering is promoted by a higher temperature of the sheets when rolled, or by soaking them longer than usual, such treatment tending to burn out the carbon and permit separation of the fiber.

Galvanizing.—Much the same applies to other articles as has been described under the head of galvanizing wire rods. It is pretty generally recognized that it tends to produce brittleness, mainly, no doubt, from the causes mentioned, and possibly also from the brittle nature of the zinc-iron alloy which forms at the junction of the two metals when they are properly united.

All that can be done is to keep the steel as soft as possible up to the stage of pickling as described for wire, and heat the goods as hot as possible after pickling (short of oxidizing the surface and preventing the adhesion of the zinc) so as to expel hydrogen and restore softness, and avoid all chilling, and cool as slowly as possible, after leaving the zinc bath.

Cold Drawing or Rolling has been referred to. In large sizes as the work penetrates the mass still less, the compression and distortion of the surface sets up a state of strain and sometimes minute transverse cracks, predisposing to fracture. The effects of cold hammering, as seen by the microscope, have been described by the writer in a former paper*, and cold-drawn rods show similar effects.

As both the pickling which preceded it and the cold drawing have such hardening effects, it is most desirable that the steel should be in a very soft condition prior to these operations. Therefore, where possible, it should be annealed by rapid reheating to cherry-redness, as previously described, or by the ordinary methods; or, failing this, finished sufficiently hot, or cooled

* "Journal of the Iron and Steel Institute," 1899, No. II. "Practical Microscopic Analysis."

sufficiently slowly, after rolling (whilst avoiding large grain, and want of toughness on that score), to also avoid rolling hardness.

Rods predisposed to brittleness, either by finishing above critical temperature, and thus leaving the grain too coarse, or by finishing at or near blue heat, are, when subjected to the further hardening and straining effects of pickling and cold drawing, almost certain to become very brittle.

These few examples should suffice to illustrate some of the directions in which to look for causes for unusal behavior; but, of course, the number of possible causes which might bring about a result is very large, though a careful consideration of each particular case should facilitate a correct solution.

SECTION VI.

Tests—Standard Required.

With reference to steel being termed "brittle," unweldable, or faulty in any other respect, in view of all that we have seen as to the treatment steel gets, and how it is affected thereby, it seems only reasonable that there should, for all types of manufactured article, be some tests which, when made under clearly defined conditions, should be publicly recognized and accepted as legitimate (as there are for certain requirements, such as boiler plates, ship plates, rails, &c.), and to which any sample under question can be referred as to a standard. At present, if a piece of steel fails in any process, or will not stand any test that the user imposes upon it, irrespective of any treatment it has received up to then, it is condemned and the maker blamed (and told that it is no good unless it will stand such treatment—ignoring the enormous differences in effects that a slight difference in treatment, such as might easily occur without being known, may have).

For instance, it does not seem reasonable to designate as "brittle" a narrow piece of strip or plate with the rolling hardness still in it, and say, 1½ inches to 2 inches wide, both edges being cold sheared and not trimmed off in any way, because it will not stand bending close double along the line of rolling.

A good deal of steel will stand such a test, but when it does, it

SEC

Classified Under Heads of Faults of Differe

Type of fault and manifestation.	By whom originated (probably), provided material as sent away, of composition within limits specified and free from visible defects.*		
Unsoundness:			
Hollowness	Occasionally (if clean)	User	W
Lamination	Generally (always if enclosed slag or dirt found)	Maker	Se
Seaminess (when machined)			
Split ends			Ro
Laps	If clean, roller, whether maker or user		Pi
	If dirty, or other signs of unsoundness	Maker	
Surface defects:			
Cracks	Generally (always if enclosed dirt)	Maker	Cr
Scabs			
Spilliness (wire)			
Blisters (sheets)			Se
Ditto	If bright inside, but large and isolated, or in groups	Maker	Bl
Ditto	If bright inside, but small and thickly distributed, probably	user	Im
	Occasionally	maker	Spo
Streaks	(Unless accompanied by lamination at edges of streaks)	User	Fo
Indentations			Le
Roughness or pitting			
Dryness	Generally	Maker	Ro
			Se
Opening at ends	Occasionally	User	Ov
Red shortness	Frequently (to some extent)§	User	Ov
			W
Won't weld well	Ditto	Ditto	Un
Rough ("saw") edges	Occasionally.	Maker if all over piece, or user	Qu
Won't forge well	If only part, say one corner	User	Bur
Brittleness:			
Breaks short off	Generally (unless composition seriously at fault)	User	Eit
Cracks in punching, stamping or shearing			If c g
Hardness:			
Won't bend enough	Ditto	Ditto	
twist enough (wire)	Ditto	Ditto	
Punches and shears too hard	Ditto	Ditto	If
Tensile test too hard	Ditto	Ditto	fin gra
			Exc in
Over-softness:			
"Lugging" — Won't cut crisp and turn smooth	Generally	User	To
Tests too soft	Ditto	Ditto	Fi

Excepting most forms of unsoundness, it is probable that faults
composition, if wrong, is so in a whole blow, as there is no material va
whilst any variation in the heat and treatment given by maker does no
maker and user are in varying degrees responsible. If (1) the steel is
clearly informed as to the purpose for which it is intended or treatme
will condemn them; (3) the characteristics of each make of steel are n

* Except in the case of ingots or large blooms, slight surface crack

† Dixon Brunton, "Wire and Wire-Drawing," "Journal of the W

‡ Ridsdale, "Practical Microscopic Analysis," "Journal of the In

§ Maker, for his own sake, will keep S and other impurities low, a
as defective, and does not leave works.

SECTION VI.—MANIFESTATIONS.

ults of Different Types, Appearing After Treatment by the User for Tracing their Probable Source.

robably), pro-sent away, of limits speci-sible defects.*	Probable cause.	Tests for identifying cause.
)..... User	Work at too low temperature, not penetrating mass evenly, and causing "creep" of material,† particularly in forgings‡	Microscope shows abnormally distorted grain, &c.
enclosed slag .....Maker	Segregation and (or) insufficient cropping	Presence of slaggy matter high in manganese.
ther maker or .... s of unsound- .....Maker	Rolled from cold-sheared bars, some of ends of which have split and not been noticed	Examine ends of unrolled bars left carefully.
	Pipe in ingot imperfectly cropped, or crack not worked out	Eye or microscope can generally discriminate.
enclosed dirt) Maker	Cracks, &c., imperfectly rolled up, but closed up enough to escape notice	Eye or microscope shows lapping, and generally scale or dirt.
large and iso- .....Maker t small and ed, probably	Segregation ingot top... / Blowholes ingot top..... } Insufficient cropping	Contain CO and N if formed before annealing.
	Improper pickling	Microscope shows normal-sized grains, and soundness before pickling, or in parts other than actual blisters.
	" " preceded by overheating or soaking	Microscopic examination shows large grain or bands.
.....	Sponginess; insufficient cropping	Microscope shows unsoundness before pickling, or in parts other than actual blisters.
d by lamina- reaks).....User	Foreign substances, as coal, coal ash, scale, &c., rolled into surface through getting between rolls and piece, or between pairs or folded sheets. Frequently sticks more if sheets hotter, and hence softer than usual.	If scraped off, sheet underneath sound. Color and simple test shows what it is. Coal (black) burns brown or white; coal ash brown (oxidized); coal ash white (not oxidized). Scale contains 60 to 70 per cent. iron.
	Left when foreign substances become detached	Microscope shows larger grain if heated hotter.‡
.....Maker	Red shortness	Analysis shows S and Mn, and hence if these are at fault—
	Segregated parts in center (least cohesion) not all cropped off	Excess of impurities on insides.
.....User	Overheating, sticking in rolls, &c.	Color and scale shows this, and if composition quite suitable for purpose, overheating probable cause.
xtent)§ ..User	Overheated or "soaked" too long	Generally accompanied by thick scale. Microscope shows large grain or bands outside, good normal grain inside if piece thick enough.
Ditto .. r if all over	Want of a flux	Make welding test with flux.
	Unsuitable quality specified	Analysis in conjunction with purpose shows this.
	Quality has not sufficient margin of "body"	Ditto.
corner...User	Burnt	Generally accompanied by thick scale. Microscope‡ shows large grain or bands outside, good normal grain inside if piece thick enough.
nposition se- .....User	Either one or more of the following in greater or less degree:	
	If coarse grain: Finished too hot or: Furnace too hot; Rolled hot to spare machinery; Rolled very quickly; Large sections. "soaked" too long: Delay in mill—steel left in furnace or over night. Over-annealed. → Cooled very slowly in large heaps, &c.	Fracture generally shows coarse grain. Microscope shows larger grain than normal for that section, or structureless bands, especially at outside of piece.‡
Ditto Ditto Ditto Ditto	If fine grain: Finished too cold or chilled whilst at blue heat: First piece; "Stalling" of piece or other delay; Thin sections; Cold floor, &c.; Spread too much; Rain or intentional watering. → Cooled rapidly	Microscope shows abnormally distorted grain, &c.‡
	Omitting annealing where required.	In samples rendered brittle by any of causes named, heating for a minute or two to cherry-red and chilling in water if C not over 0.10 per cent., or cooling in air if above this, restores toughness, unless sample has been thoroughly spoiled. Microscopic examination also shows grains restored normal.‡
	Exceptionally severe pickling; cold drawing, rolling, or hammering or galvanizing.	
.....User	Tools too blunt or cut too heavy / Unsuitable quality specified: Before asking for harder steel make sure it will not do harm in other way. Try sharper tools or lighter cut first.	Comparative tests, using same tool or drill with pieces considered right, will show whether steel is soft or tools blunt.
Ditto ..	Finished rather hotter or cooled slower than usual, sufficiently to make steel softer.	Microscope may show larger grain ‡

robable that faults which affect only a small proportion of the steel, and not a whole cast, are not due to the maker, but to the user; for the ere is no material variation between one part and another of the same blow, except that occurring from the outside inwards, due to segregation, en by maker does not count, as it is obliterated on reheating by user. Many faults are, however, due to a combination of causes for which both . If (1) the steel is normally taxed almost to the limit of its endurance by the processes it is made to go through; (2) the maker has not been ntended or treatment it will receive, particularly as to soundness when worked into machined articles, the slightest speck or seaminess in which make of steel are not studied by the user, but all worked indiscriminately; the maker's responsibility for trouble should be less. , slight surface cracks if chipped deeply.

" "Journal of the West of Scotland Institute," No. 4, January, 1900, page 119. Also "Mannesmann" process is an example.

" "Journal of the Iron and Steel Institute," 1899, No. II.

ner impurities low, as, if seriously at fault, heavy draughts on ingots at once reveal red-shortness, and will not roll down clean, so gets thrown out

is not necessarily that the quality of the steel itself is exceptionally good, or when it does not that it is inferior, but may be simply that the sum of the treatment it has received has not been too severe. Even two cuts with the same shears do not necessarily set up an equal strain; from the same piece of plate sheared into cotters some may crack whilst most stand. Therefore, when pieces do not stand, as the strains or hardness set up by treatment are an unknown quantity, they should be removed before testing, and thus the pieces put on a known basis by heating rapidly to cherry-redness for a minute or two, and according to composition, purpose, &c.:

Allowed to cool slowly in lime, ashes, &c.;
Allowed to cool naturally in air;
Chilled in water.

Again, any steel which will conform to the bend tests specified by Lloyd's for boiler plate or ship plate should surely not be considered brittle.

Also a standard system for allocating any trouble that arises is desirable, and for defining the lines on which it shall be argued. In the table of faults of various types are briefly indicated a few tests, mechanical, microscopical, thermal and chemical, which might serve to trace them to their probable source, and thus enable the trouble to be stopped in future. They are, of course, only quite general, as each particular case will probably suggest its own tests.

It may be asked, What steps should any one take who is wishful to always give the best treatment, in order to train the men who do the work?

This is not a question of a pyrometer or of drawing up lists of proper temperatures, either in degrees centigrade or in terms of color. Even if they can measure these, and know when they have got them, this is not enough. It all comes back to this, that since no outsider knows any one's exact conditions or chief troubles, the only thing is for each one to study these, and thus decide in what direction to make alterations—possibly what has been said may be some help—then try pieces under different

conditions, finishing hotter and colder, cooling more or less rapidly, &c.

No doubt many matters will have been noted on which further information is desirable, and amongst these the following occur to the writer:

1. Condition of absorption of hydrogen, and production of pickling brittleness and blisters at will, whether due to strength of acid, length of time, galvanic action, &c.

2. How far pickled articles can be heated (to soften them) without interfering with the zinc taking.

3. Whether galvanizing hardness is due to anything other than the blue-heat treatment.

4. Means of annealing cold-rolled goods, plain and bright, without destroying their bloom, color or brightness.

5. (*a*) Authenticated instances of (soft) steel which was known in the first place to have neither had large grain nor been in a state of strain, and known to be quite tough, which had become brittle and crystalline by vibration or fatigue only.

(*b*) Means of rendering tough fine-grained steel free from state of strain, coarse-grained and brittle at will by vibration or fatigue under known conditions.

6. Relative effect of blue-heat working on steel of different carbon contents. (It is difficult on a small experimental scale to insure a uniform degree of blue-heat work.)

PROGRESSIVE TRIALS OF U. S. BATTLESHIPS.

NAVY DEPARTMENT.

WASHINGTON, D. C., *February 12, 1902.*

Sir: We have the honor to make the following report concerning the progressive trials of the *Alabama*, *Massachusetts* and *Kearsarge*, held on the Barren Island course, in Chesapeake Bay, in November and December last.

This report contains the following:

1. General remarks concerning the times, conditions and circumstances of the trials.
2. Description of methods in connection with deck observations and records.
3. Descriptions of methods of signaling between deck and engine rooms and of making successive runs.
4. Description of engine and fire-room methods, drills and records.
5. Data recorded.
6. Data plotted.
7. Conclusions and recommendations.

GENERAL REMARKS.

In obedience to orders we reported to the Commander-in-Chief of the North Atlantic Squadron, on Wednesday, November 20, 1901. The *Massachusetts* left the yard on the afternoon of Thursday, November 21st, and the *Alabama*, on which vessel we took passage, left later in the same afternoon, anchoring for the night at Tompkinsville. The next day she got under way and proceeded to Chesapeake Bay. On the way down preliminary trials were made to determine the relation between speed and revolutions, as later described. Instruments were erected, tested, etc., and general preparations made.

The *Alabama* and *Massachusetts* both reached the trial course during the afternoon of November 23d. The weather conditions

on the morning of November 24th were very favorable and it was proposed to begin the trial of the *Alabama.* About the time the trial was started, however, the weather began to cloud up and the conditions grew rapidly more unfavorable, so that at the end of the second run the weather was almost too thick to see the ranges, and very shortly thereafter the ranges could not be made out at all, so the trial was abandoned for the day after one run at maximum power and a second run at about 100 revolutions.

The next day the weather conditions were not favorable, but as the wind, though undesirably strong, was almost parallel to the direction of the course, and as the *Alabama* was rather short of coal, it was concluded to complete the trial, beginning at the lower speed and working up to about 100 revolutions.

After the completion of this trial we were transferred to the *Massachusetts*, and found that on the way down the observers on this vessel had been carefully drilled and everything was ready for the trial. The weather on Thursday, November 26th, was, however, too rough to conduct the trial, so it was postponed until Wednesday, the 27th, when it was successfully carried out under weather conditions more favorable than in the case of the *Alabama*, but still leaving something to be desired.

After the completion of the *Massachusetts*' trial we returned to Washington. We proceeded again to New York and reported on board the *Kearsarge* on Saturday, December 7th, the vessel leaving the navy yard that afternoon and anchoring at Tompkinsville over night. She reached the course Monday, December 9th, preliminary trials and drills having been held on the way, and the progressive trial was run on the morning of Tuesday, December 10th. The conditions during this trial were very similar to those during the trial of the *Massachusetts*, as will be seen from the record.

On the completion of the *Kearsarge* trial we returned to Washington, and since then have been engaged from time to time in working up the data obtained, which is submitted herewith.

There were 882 indicator cards taken from the three ships, and the time required to work out these cards has been the cause of delay in submitting this report.

DECK OBSERVATIONS AND RECORDS.

In addition to the officers navigating and conning the ship there were three observers on deck. The Weaver speed recorder was set up on deck for the purpose of recording time and revolutions on the course. In the case of the *Massachusetts* the recorder was placed in the emergency cabin, which is on the after bridge. Wires were led from it to the electrical speed-counter attachments on the port and starboard shafts below. The wires from the attachments on the shafts to the indicators on deck were disconnected, and the speed-recorder wires connected in their place. On the *Kearsarge* and *Alabama* the recorder was placed in the pilot house forward. In their case there was an electrical speed recorder from each shaft conveniently located close by. These were opened and short wires from the Weaver instrument connected to their binding posts. It was attempted at first on the *Alabama* to make no further change. It was found, however, that each revolution indicator had a separate battery, and that when they were connected up in this manner through the Weaver machine the record of the machine was erratic, so each separate battery was cut out, the wires to it being short-circuited, and nine dry cells used with the Weaver recorder were cut in for a common battery to the two shaft indicators. This was found to work very well on both the *Kearsarge* and *Alabama*.

The forward observer for the Weaver recorder was located in each case very close to the instrument, having a short length of wire. The instrument is designed with a bell, and each observer has a handle with two buttons, one to ring the bell for warning, and the other to make a mark on the tape as the line is crossed. With the instrument erected on deck, however, the operator can see for himself how close he is to the ranges and can start the instrument without warning from the observer.

It was found that the connections were liable to give trouble without notice, so in the later runs the bell was cut out entirely and both wires from the observer connected to the range-mark post of the recorder so that either button would work the range signal pens. As there is sometimes uncertainty as to whether a

range mark is made by the observer or is accidental from some other pen, the best practice was found to be as follows:

When crossing the range the forward observer pressed the button once, at the same time singing out "mark" loud enough for the operator of the intrument to hear him. The operator watched the tape and could readily see the range mark as made and identify it by a pencil mark. The after observer pressed his button three times, once just as the ranges were on and twice more as quickly as he could. The operator of the instrument watched closely after the forward observer's record was seen until the after observer's record appeared, when he identified that also with a pencil mark.

Although from poor contacts and accidental failures of connection there were a number of cases where one of the range observers failed to make his mark on the tape, there was no case during the thirty-seven runs of the three ships when they both failed in the same run. In one case the time switch appeared to lose contact during a run and a few seconds were not recorded on the tape, but the operator of the instrument noted the sudden failure of the time record, and upon pressing the switch and remarking a good contact the time record was resumed. The gap was so short that it was readily filled by interpolation. In another case, during one run of the *Massachusetts*, one of the officers in the emergency cabin accidentally broke the connection of the main battery wire, making the record blank for a number of seconds. This, of course, rendered the time observations on the course a failure, but the revolutions were obtained with sufficient accuracy from the record taken from and after the break.

In order to have a check upon the instrument and something to rely upon in case of failures, the forward observer in each case used a stop-watch, which he started for each run at the instant of crossing the first range and stopped at the instant of crossing the second. The stop-watch times on the course were recorded and agreed very closely with the records of the Weaver recorder. The latter, however, were taken in thirty-six of the thirty-seven cases as being more accurate, the stop-watch record being used only in the case where the Weaver record was a failure.

The Weaver machine makes an exceptionally long record, par-

ticularly for the slow runs. The work of counting the seconds and revolutions from its tape record is very tedious and requires to be very carefully done to avoid errors. It was found that by allowing the machine to partially run down and taking care not to wind it up fully at any time, it ran more slowly and made a shorter tape, which is somewhat preferable, although the number of revolutions and seconds to be counted are the same.

Two machines were available for the *Alabama* and *Massachusetts* runs. One had recently been set in thorough order by the makers; the other had been overhauled at the Washington yard and had extra vanes put on its brake to make it run more slowly. As a matter of fact, it ran out tape at about half the rate of the other, and was used for all three runs.

When using the Weaver recorder the work of the deck observers is very simple. It required practically no preliminary drill, and there was no hitch from them in any case.

The connections to the machine are somewhat complicated, and it requires to be carefully handled, being started a sufficient time in advance of each run to make sure that all its functions are being properly performed.

On the *Alabama* and *Kearsarge* the machine was operated by Naval Constructor Taylor. On the *Massachusetts* the machine was set up and connected by him before the vessel left the yard and then disconnected. It was re-connected and practiced with by Lieutenant Salisbury on the way down, and he operated it during the progressive trials.

The chronometers in connection with the two machines had been recently overhauled. They were shipped by express several times, and necessarily handled somewhat roughly at times, but it apparently did not affect them adversely. They have been running for some time since the last trials, and with a rate in each case which is entirely negligible for the purpose of speed trials.

ROUTINE OF TRIALS AND SIGNALS.

On each vessel there is a gong from the after bridge to each engine room. The after observer was located in the immediate vicinity of these pulls on the *Alabama* and *Kearsarge*, and the forward observer on the *Massachusetts*, men being stationed by

each pull. It was understood between the bridge and the engine room that when the engine room reported everything in readiness to begin the trial the ship would steam back and forth over the course, making a wide turn at each end, trying to get a straight run of at least a half mile in each case before entering the course. The revolutions were dropped from run to run in the engine room as described below.

About five minntes before entering the course the officer of the deck blew one long whistle or siren blast. It was found advisable to notify the starboard engine room in each case immediately after the whistle had blown. This was a cautionary signal to notify all concerned that the run was about to begin. About one minute by estimate before reaching the course the observer at the bell pulls had two bells rung in each engine room. This was the stand-by signal to all engine-room observers. At the instant of entering the course one bell to each engine room was pulled as a signal of execution to the observers below to begin taking data. One minute before leaving the course two bells were again pulled, and at the instant of crossing the last range one bell was given to each engine room again. This system worked in a thoroughly satisfactory manner, and we would suggest no changes in future trials.

There was some difficulty found in steering these large vessels on the course without using a good deal of helm at times, particularly at the lower speeds.

ENGINE AND FIRE-ROOM METHODS AND RECORDS.

On the run from New York to the trial course the observers were drilled at their stations, which were as follows:

(a) An officer was stationed at each main-engine cylinder to take indicator cards, in accordance with the above signals.

(b) Observers were also stationed in each engine room to record the time and counter at the instant of entering and leaving the course, and also to obtain such other data as is specified in the steam log.

(c) A single observer was stationed in the fire room to obtain the general fire-room data on each run, and to communicate the signals to the fire rooms.

The trial of each vessel consisted of one or more runs over the course at the highest speed obtainable without undue forcing, and then a series of runs at intervals of about one knot from the highest speed down to a speed of about six knots per hour. This program was not carried out as originally intended on the *Alabama* on account of weather conditions, two runs only being made on November 24th, and the remainder on the following day, beginning at about six knots and working up.

The *Alabama* and *Massachusetts* were run over the course once at the highest speed and the *Kearsarge* three times.

The high speeds were run first in order to obtain the best results with clean fires.

In order to adjust the speed of the engines promptly, for each run over the course, a steam gauge had been fitted to each H.P. steam chest, graduated in pounds, and a series of short preliminary runs at varying speeds, in free route, had been made on the run from New York, from which a curve of gauge pressures, plotted on revolutions, had been constructed, so that in making the runs over the mile it was only necessary to bring this gauge to the required pressure by manipulating the throttle and keeping the boiler pressure constant, in order to obtain the desired speed of the engine. Having decided on the speeds desired on the various runs over the course, a table was made from this curve showing the pressure to be maintained in the H.P. steam chest on each run, and each run to be made was assigned a number.

The method of procedure at the trial course was as follows:

At each signal of the whistle (five minutes before entering the course) the throttle of the starboard engine was adjusted to bring the pointer of the gauge to the pressure corresponding to the desired number of revolutions; and the port engine was made to follow the starboard engine without reference to its gauge in order that the speed of both engines should be the same on the course.

The signal (two bells), at one minute before crossing the line, was intended as a warning signal to all observers; and at the signal of execution (one bell) the handling of the throttle ceased. Three sets of indicator cards were taken by each card taker in quick succession, and the time and counter noted by the observer stationed for that purpose.

A messenger was stationed in each engine room to collect the cards, which were placed in separate envelopes for each run. The envelopes were then sealed and marked with the number of the run, and starboard or port engine, the cards being subsequently marked with the corresponding data taken from the log sheet. The fire-room data was entered on the log sheets after the trial was completed.

A messenger was stationed at the engine-room voice tubes to communicate with the fire rooms, keeping them informed of the beginning and end of each run, so that the fires could be regulated accordingly, and in order to prevent possible confusion, a messenger was also dispatched from the bridge to the engine room at the end of each run, with a memorandum of the number of the next run to be made.

After the runs on the course were completed, the friction runs were made, it being understood that after they were begun the helm would be kept amidships and not disturbed unless necessary. For this test the engines were run at a series of speeds (not on the course and only long enough for the ship to gather headway corresponding to the speed of the engine), dropping by about five revolutions from the lowest speed over the course to the slowest speed at which the engines would turn over steadily, and three sets of cards were taken at each speed on signal of a whistle blown in the engine room. These cards were used in obtaining the mean pressure of initial friction as shown on the curves attached hereto.

DATA RECORDED.

There is appended a record of the data recorded on the trial, consisting of Appendix A–A, giving the deck record of the progressive trial of the *Alabama;* Appendix A–K, giving the deck record of the progressive trial of the *Kearsarge*, and Appendix A–M, giving the deck record of the progressive trial of the *Massachusetts.*

Appendix B–A contains a record of data taken on the progressive trial of the *Alabama*, B–K of the *Kearsarge*, and B–M of the *Massachusetts.* These B appendices show the final data used in connection with speed, power and revolutions.

The indicated horse power entered, as calculated from the cards, is the average in each case of the three cards taken on each cylinder on each run.

DATA PLOTTED.

From the data recorded the curves of speed and power have been obtained as follows:

Appendix C–A shows the data recorded as plotted for the *Alabama*, C–K for the *Kearsarge*, and C–M for the *Massachusetts*. In plotting these curves the apparent speed with or against the tide was set up above the revolutions for the run, and fair curves of speed with and against the tide drawn through, the mean curve of course giving the true speed in still water corresponding to the revolutions. Similarly, each power was set up above the revolutions corresponding and a fair curve drawn through. As the displacements of the vessels upon these progressive trials were but little greater than their displacements on their official trials, the speeds and revolutions and powers of the official trials were also plotted on these diagrams, and the upper part of the curve drawn with appropriate reference to them.

The progressive trials of the *Alabama* and *Massachusetts* included the period of slack water, which is undesirable. It is evident, however, from the curves that in spite of this the results are satisfactorily accurate.

Appendices D–A, D–K and D–M, referring respectively to the *Alabama*, *Kearsarge* and *Massachusetts*, show the curves of indicated horse power, revolutions, indicated thrust and slip plotted upon speed.

Appendix E shows the curve of mean effective pressure for the three ships plotted on revolutions, and extended down through the spots obtained on the friction runs to the zero of revolutions in order to determine the mean effective pressure corresponding to the initial friction.

CONCLUSIONS AND RECOMMENDATIONS.

In conclusion we recommend that the following precautions be taken in future trials of a similar nature in order to insure success.

1. Coal should be of good quality. The coal used on the trials herein reported on was very poor, showing by analysis 35.34 per cent. of ash, which made it impossible to obtain as high a speed as might have been otherwise obtained.

2. The necessity of thoroughly drilling the observers at their stations and making them familiar with the system of signals is most important, as the time on the mile, at high speeds, is very short, and delay or inexperience on the part of any observer will result in the failure of the record.

3. As regards the general methods and routine for future trials, we would not recommend any material departure from the methods which were found to work successfully in the case of these three battleships. We would suggest, however, that in every case three runs be made over the course at top speed instead of one. This was done in the case of the *Kearsarge*, and the results were more satisfactory for plotting than in the case of the other two vessels.

4. For ships of this class it is believed that progressive trials can be run by the personnel of the ship, but to secure the best results with smaller vessels more observers will be necessary than can be obtained from the ship's force.

5. Under the conditions existing at the course it was difficult in the case of each vessel to obtain accurately the trial draught. We would suggest that internal draught tubes somewhat similar to gauge glasses might be so located on many vessels as to enable the mean draught to be readily and accurately determined when the surface of the water is comparatively rough. Such fittings would be found very useful in connection with all speed trials—including official trials—and it is believed would also be found of use in the ordinary service of a man of war.

A report identical with the above has been submitted this day to the Chief of the Bureau of Construction and Repair.

Very respectfully,

D. W. TAYLOR,
Naval Constructor, U. S. N.

C. E. ROMMEL,
Lieutenant, U. S. N.

TO THE CHIEF OF THE BUREAU OF STEAM ENGINEERING.

APPENDIX A-A.

DECK RECORD OF PROGRESSIVE TRIAL.

Name of vessel—*Alabama.*

Vessel undocked—November 19, 1901.

Condition of bottom when undocked—freshly painted.

Painted with McInnes—one coat anti-corrosive, one coat anti-fouling.

Itinerary from undocking to date of trial:

November 21, from Navy Yard to Tompkinsville.

November 22, left Tomkinsville.

November 23, arrived Barren Island Course.

Date of trial—November 25, 1901.

Place of trial—Barren Island Trial Course, Chesapeake Bay.

Progressive trial began about 7·53 A. M., local time.

Progressive trial ended about 11·18 A. M., local time.

Before trial, at 1·00 P. M., November 24, draught forward, 24 feet 1 inch; aft, 23 feet 11½ inches.

After trial, at 1·30 P. M., draught forward, 23 feet 10 inches; aft, 24 feet ½ inch.

Assumed trial conditions: Draught forward, 23 feet 11½ inches; aft, 24 feet 0 inches.

Mean draught, 23 feet 11¾ inches; density of water on course, 1.018—determined by hydrometer of medical department.

Trial displacement, 11,734 tons

Tidal data from chart of course and tide tables for 1901:

H. W. on course	12·25 A. M.	12·54 P. M.
L. W. on course	6·54 A. M.	
Before ebb—H. W. slack on course	4·10 A. M.	4·39 P. M.
Before flood—L. W. slack on course	10·14 A. M.	
Maximum flood on course	1·29 P. M.	Maximum strength by tables 0.7 knots.
Maximum ebb on course	7·14 A. M.	Maximum strength by tables 0.8 knots.

N. B.—N. W. wind probably made ebb stronger and last longer than tables would show.

BRIEF RECORD OF TRIAL.

Reported by Naval Constructor D. W. Taylor, at Speed Recorder.
Forward observer, Ensign Evans; after observer, Lieutenant Robinson.
November 25, 1901.

No. of run.	Direction of run.	Entered course about—	Stop-watch time on course.		Nature of record from instruments.	Remarks.
			Min.	*Sec.*		
1	S.	7°53	10	14.75	Good.	Steers badly at this speed.
2	N.	8°28	9	54.6	Do.	
3	S.	8°54	6	14.75	Do.	
4	N.	9°14	6	42.6	Do.	
5	S.	9°34	5	27	Do.	
6	N.	9°50	5	40	Do.	
7	S.	10°08	5	03.6	Do.	
8	N.	10°25	4	49.1	...	
9	S.	10°41	4	33.75	...	
10	N.	10°56	4	09.25	...	
11	S.	11°14	4	07.6	...	
			From November 24.			
1	S.	1°50	3	58.75	...	Flood.
2	N.	2°05	3	56	...	

WIND AND WEATHER DURING TRIAL.

Time.	Direction of wind.	Force of wind.	Condition of sea.	Bar.	Thermometer, dry bulb.
8	N. W. by N.	5	Numerous white caps,	29.56	46
9	N. W. by N.	5	Do.	29.56	47
10	N. W. by N.	5	Do.	29.56	47
11	N. W. by N.	5	Do.	29.57	47

APPENDIX A–K.

DECK RECORD OF PROGRESSIVE TRIAL.

Name of vessel—U. S. S. *Kearsarge.*

Vessel undocked—December 5, 1901.

Condition of bottom when undocked—clean, painted.

Painted with one coat Holzappel's anti-corrosive paint and one coat Holzappel's anti-fouling paint.

Itinerary from undocking to date of trial:

Left Navy Yard, New York, December 7; arrived Tompkinsville December 7, 1901.

Left Tompkinsville December 8; arrived Trial Course December 9, 1901—2 P. M.

RECORD OF DATA TAKEN ON PROGRESSIVE SPE

No. of run.	Direction of run.	Approximate time of entering course.	Time on course, in seconds.				Revolutions of shafts.									
							Starboard.					Port.				
			By stop watch.	From Weaver recorder		Used in calculations.	On course by Weaver recorder		Taken in engine room.		Used in calculations.	On course by Weaver recorder		Taken i engine roo		
				Forward observer.	After observer.		Forward observer.	After observer.	From counter at beginning and end.	One minute by count during run.		Forward observer.	After observer.	From counter at beginning and end.	One minute by	
1	S	7·53	614.75	616.38	614.48	615.43	348.51	347.90	350	Record not taken.	348.20	335.52	334.83	336		
2	N	8·28	594.6	594.90	(*a*)	594.90	476.70	(*a*)	477		476.70	458.95	(*a*)	459		
3	S	8·54	374.75	375.00	373.70	374.35	374.95	374.00	374		374.47	370.70	369.65	371		
4	N	9·14	402.6	402.82	402.25	402.54	428.75	428.25	429		428.50	430.70	430.15	429		
5	S	9·34	327.0	326.80	326.20	326 50	386.18	385.87	386		386.03	387.10	386.60	387		
6	N	9·50	340.0	340.05	(*a*)	340.05	408.70	(*a*)	409		408.70	412.75	(*a*)	412		
7	S	10·08	303.6	303.90	303.10	303.50	400.25	399.50	400		399.87	399.25	398.50	399		
8	N	10·25	289.1	289.45	(*b*)	289.45	399.15	(*b*)	400		399.15	399.00	(*b*)	399		
9	S	10·41	273.75	274.20	274.00	274.00	411.40	411.25	411		411.33	409.85	409.85	411		
10	N	10·56	249.25	249.56	249.50	249.53	392.35	392.25	392		392.30	400.40	400.25	396		
11	S	11·14	247.6	247.95	248.15	248.05	413.74	413.90	414		413.82	415.00	415.40	416		
12	S	1·50	238.75	240.90	240.75	240.82	413.70	413.40	414		413.55	415.20	415.10	415		
13	N	2·05	236.0	235.85	236.20	236.02	385.95	386.50	387		386.22	402.35	403.05	403		

(*a*) After signal failed to record at beginning of run.

(*b*) After signal failed to record at en

FRICTION RUNS.

A	...	...	...	...	...	..	...	...	...	29	...	...	..	...	2
B	...	...	...	...	...	...	...	...	...	25	...	...	...	...	2
C	...	...	...	...	...	...	...	...	...	20	...	...	...	...	2

Port.					Indicated horsepower, by cards.						
Taken in engine room.		Used in calculations.	Apparent speed, knots.	Mean revolutions per minute.	Starboard.			Port.			Total average for run, both engines.
From counter at beginning and end.	One minute by count during run.				H	I	L	H	I	L	
336		335.18	5.850	33.31	85.67	73.22	17.93	73.91	67.73	32.54	351
439		458.95	6.051	47.18	159.51	113.42	127.21	147.67	83.23	185.18	816.22
371		370.18	9.620	59.67	249.65	213.2	243.95	242.25	169.52	253.10	1,371.67
429		430.43	8.943	64.01	312.8	284.16	292.86	334.78	277.7	374.7	1,877
387		386.85	11.027	71.02	388	351.5	432.05	396.72	314.74	461.45	2,344.45
412		412.75	10.588	72.48	435.59	439.2	422.95	477.07	430.5	497.15	2,702.46
399	Record not taken.	398.87	11.862	78.95	546.7	546.3	538.8	530.97	472.15	558.1	3,193.04
399		399.00	12.438	82.72	648.53	653.25	623.65	647.85	584.4	644.75	3,802.43
411		409.85	13.133	89.87	777.6	822.9	812.0	749.75	705.6	807.1	4,674.95
396		400.33	14.428	95.29	905.92	967.45	968	999.48	1,034.8	1,000.45	5,876.1
416		415.20	14.514	100.27	1,046.10	1,166.9	1,213.4	1,051.4	1,109.95	1,163.7	6,751.45
415		415.15	14.950	103.24	1,155	1,278.4	1,385.7	1,146.05	1,203.5	1,415.1	7,583.75
403		402.70	15.253	100.19	951.5	1,066.8	1,205.9	1,213	1,340.5	1,338.6	7,116.3

ecord at end of run.

NOTE.—Nos. 12 and 13 are runs of November 24, 1901.

RUNS.

...	29	...	...	29	60.68	62.58	25.37	63.98	55.76	29.97	299.34
...	25	...	...	25	63	60.5	11.92	78.12	60.95	1.33	274.82
...	21	...	...	20.5	45.02	43.42	.80	58.28	41.04	.48	188.18

RECORD OF DATA TAKEN ON PROGRESSIVE SPEED

No. of run.	Direction of run.	Approximate time of entering course.	Time on course, in seconds.				Revolutions of shafts.								
							Starboard.					Port.			
			By stop watch.	From Weaver recorder		Used in calculations.	On course by Weaver recorder		Taken in engine room.		Used in calculations.	On course by Weaver recorder		Taken in engine room	
				Forward observer.	After observer.		Forward observer.	After observer.	From counter at beginning and end.	One minute by count during run.		Forward observer.	After observer.	From counter at beginning and end.	One minute by count during
1	N	10·15·30	227.00	235.40	226.40	226.40	440.15	423.45	424	113	423.45	440.70	424.20	425	11
2	S	10·28·55	214.25	214.30	214.75	214.52	389.74	390.69	391	109.5	390.21	388.34	389.08	390	11
3	N	10·42·00	234.00	233.87	234.19	234.03	419.68	420.47	420	108	420.07	420.18	421.00	421	10
4	S	10·56·15	233.50	233.42	232.42	232.92	387.00	384.48	385	99.5	386.24	383.30	381.96	382	9
5	N	11·10·30	260.25	260.10	259.95	260.07	412.50	412.42	413	96	412.46	401.41	401.30	402	9
6	S	11·26·30	253.00	252.90	253.85	253.37	285.65	387.11	395	91	386.38	381.70	383.40	381	9
7	N	11·41·15	282.50	282.39	282.07	282.23	400.90	400.32	400	85.5	400.61	399.37	399.18	400	8
8	S	11·56·05	276.50	276.26	275.72	275.99	382.25	381.53	382	83.5	381.89	382.94	382.20	381	8
9	N	12·09·15	311.25	311.30	310.65	310.97	402.63	402.00	...	77.7	402.31	400.27	399.65	399	7
10	S	12·26·05	305.25	306.30	304.72	305.52	380.56	378.75	379	74.5	379.65	379.55	377.55	377	7
11	N	12·42·30	380.00	380.25	380.23	380.24	391.37	391.17	391	62	391.27	389.22	389.04	389	6
12	S	1·03·40	435.50	435.50	434.95	435.22	379.80	379.75	379	52	379.77	377.70	377.58	377	5
															FRICTION RUNS.
A	...	...	...	...	...	..	...	...	...	39.5	...	...	...	...	40.
B	...	...	...	...	...	...	...	...	...	33.7	...	...	...	...	34.
C	...	...	...	...	...	...	...	...	...	27.5	...	...	...	...	30
D	...	...	...	...	...	...	...	...	...	27	...	...	...	...	27.
E	...	...	...	...	...	...	...	...	...	19.7	...	...	...	...	20

Port.						Indicated horsepower, by cards.						
	Taken in engine room.					Starboard.			Port.			
	From counter at beginning and end.	One minute by count during run.	Used in calculations.	Apparent speed, knots.	Mean revolutions per minute.	H	I	L	H	I	L	Total average for run, both engines.
20	425	113	424.20	15.903	112.33	1,600.9	1,986.7	1,986.8	1,650.5	2,016.3	2,039.6	11,280.8
08	390	111	388.71	16.783	108.93	1,461	1,765.1	1,787.7	1,444.2	1,737.3	1,688.7	9,884
00	421	108	420.59	15.384	107.77	1,433.3	1,744.3	1,735.9	1,472.6	1,725.2	1,717.3	9,828.6
96	382	98.5	382.63	15.458	99.03	1,219.4	1,294.35	1,328.15	1,117.7	1,132.25	1,219.75	7,311.6
30	402	94	401.36	13.843	93.84	1,062	1,003.15	1,216.95	908.1	868.85	1,230.8	6,289.85
40	381	91	382.55	14.210	91.04	905.2	809.55	1,097.7	831.2	697.52	1,116.2	5,457.37
18	400	85	399.28	12.757	85.02	737.3	636.6	930.15	652.9	568.45	1,006.2	4,531.6
20	381	84	382.57	13.044	83.09	643.9	610.25	814.65	667.1	576.87	829.7	4,142.47
65	399	77	399.96	15.578	77.40	542.65	514.25	665.08	542	483.6	680.75	3,428.33
55	377	73	378.55	11.784	74.45	454.25	429.45	567	443.7	367	592.4	2,853.8
04	389	62	389.13	9.468	61.57	269.1	246.7	380.3	257.72	225.34	401	1,780.16
58	377	50	377.64	8.272	52.21	145.48	127.3	260.87	111.85	105.88	266.95	1,018.33

N RUNS.

	...	40.5	...	...	40	77.39	104.28	73.98	84.89	107.03	69.83	517.4
	...	34.25	...	...	33.97	50.1	78.29	40.58	59.8	72.35	42.08	343.2
	...	30	...	...	28.75	27.78	55.36	29.18	42.54	59.68	31.19	245.73
	...	27.5	...	...	27.25	27.55	52.64	16.62	37.19	60.56	30.32	224.88
	...	20	...	...	19.85	11.47	38.82	5.42	18.56	26.72	14.83	109.82

RECORD OF DATA TAKEN ON PROGRESSIVE SPEED TR

No. of run.	Direction of run.	Approximate time of entering course.	Time on course, in seconds.				Revolutions of shafts.								
							Starboard.					Port.			
			By stop watch.	From Weaver recorder		Used in calculations.	On course by Weaver recorder		Taken in engine room.		Used in calculations.	On course by Weaver recorder		Taken in engine room.	
				Forward observer.	After observer.		Forward observer.	After observer.	From counter at beginning and end.	One minute by count during run.		Forward observer.	After observer.	From counter at beginning and end.	One minute by count during run.
1	S	9·05·57	226	(*a*)	225.90	225.90	(*a*)	469.00	470	124	469	(*a*)	466.5	...	124
2	N	9·24·10	273	272.80	(*b*)	272.80	495.20	(*b*)	485	108.5	495.20	497 8	(*b*)	498	109.5
3	S	9·40·50	260	259.80	260.15	259.97	455.91	456.35	455	104 5	456.13	453.65	454.38	454	...
4	N	9·55·48	288.5	288.25	287.92	288.08	486.73	487.18	484	101	486.95	486.50	485.94	487	101.5
5	S	10·15·05	280.5	280.72	281.18	280.95	469.89	470 57	466	100	470.23	467.67	468.25	467	100
6	N	10·33·26	302	301.97	301.52	301.75	471.88	471.01	471	94.5	471.44	473.00	472.32	455	95
7	S	10·54·16	326	326.08	326.02	326.05	462.67	462.85	463	84.5	462.76	465.89	465.93	465	85
8	N	11·10·15	381.8	(*c*)	(*c*)	381.8	(*c*)	(*c*)	471	73.5	(*c*)	(*c*)	(*c*)	473	76
9	S	11·27·43	397	397.06	(*b*)	397.06	473.10	(*b*)	472	70	473.10	474.80	(*b*)	476	72
10	N	11·44·19	413	413.18	412.67	412.93	474.90	474.58	455	64.5	474.74	476.43	476.11	457	67
11	S	12·03·59	495	494.66	494.63	494.64	488.55	488.57	488	59	488.56	487.85	487.79	484	60.25
12	N	12·25·23	575	576.88	575.42	576.15	440.60	439.58	441	45	440.09	448.90	446.65	449	47·5

(*a*) Forward signal failed. (*b*) After signal failed. (*c*) Main battery wire discon

FRICTION RUNS.

A	...	...	...	...	...	..	...	...	...	44.5	...	...	..	...	46.25
B	...	...	...	...	...	...	...	...	...	39	...	...	...	...	40
C	...	...	...	...	...	...	...	...	...	33	...	...	...	...	32
D	...	...	...	...	...	...	...	...	...	19.5	...	...	...	...	20

Port.			Apparent speed, knots.	Mean revolutions per minute.	Indicated horsepower, by cards.						Total average for run, both engines.
Taken in engine room.		Used in calculations.			Starboard.			Port.			
From counter at beginning and end.	One minute by count during run.				H	I	L	H	I	L	
...	124	466.50	15.937	124.24	1,358.5	1,308.2	1,633.04	1,166.7	1,338	1,611.9	8,416.34
498	109.5	497.80	13.197	109.20	1,099.6	886	899.6	971.3	959.9	884.9	5,701.3
454	...	454.01	13.848	105.02	989.7	770.3	811.4	802.6	749.9	782.3	4,906.2
487	101.5	486.22	12.498	101.35	868.4	663.3	733.5	745.9	695.55	738.10	4,444.75
467	100	467.96	12.816	100.19	823.8	647.25	706.4	725.30	636.05	707	4,245.8
455	95	472.66	11.931	93.86	723.6	521.8	552.6	615.9	546.6	581.25	3,541.75
465	85	465.91	11.042	85.94	548.4	368.45	390.1	481.25	364.8	428.35	2,581.35
473	76	(*c*)	9.429	78.35	400.65	267.10	310.45	359.92	266.50	328.10	1,932.72
476	72	474.80	9.067	71.62	332.64	203.34	270.10	277.71	215.35	288.4	1,587.54
457	67	476.27	8.718	69.09	295.2	186.05	221.78	247.67	177.02	225.6	1,353.32
484	60.25	487.82	7.278	59.22	206.53	112.2	159.79	167.76	114.26	157.29	917.83
449	47.5	447.77	6.248	46.23	110.72	44.09	100.61	97.30	53.93	103.28	509.93

ery wire disconnected a few seconds; record for revolutions taken before and after break.

RUNS.

...	46.25	...	...	45.37	136.75	76.98	32.25	122.9	88.53	31.97	489.37
...	40	...	...	39.50	95.21	48.88	3.71	87.36	60.16	8.78	304.10
...	32	...	...	32.50	76.43	36.67	4.31	57.35	39.75	4.33	218.84
...	20	...	...	19.75	30.58	13.22	.20	21.93	13.25	.63	79.81

APPENDIX C—A

RESULTS OF PROGRESSIVE TRIALS

OF

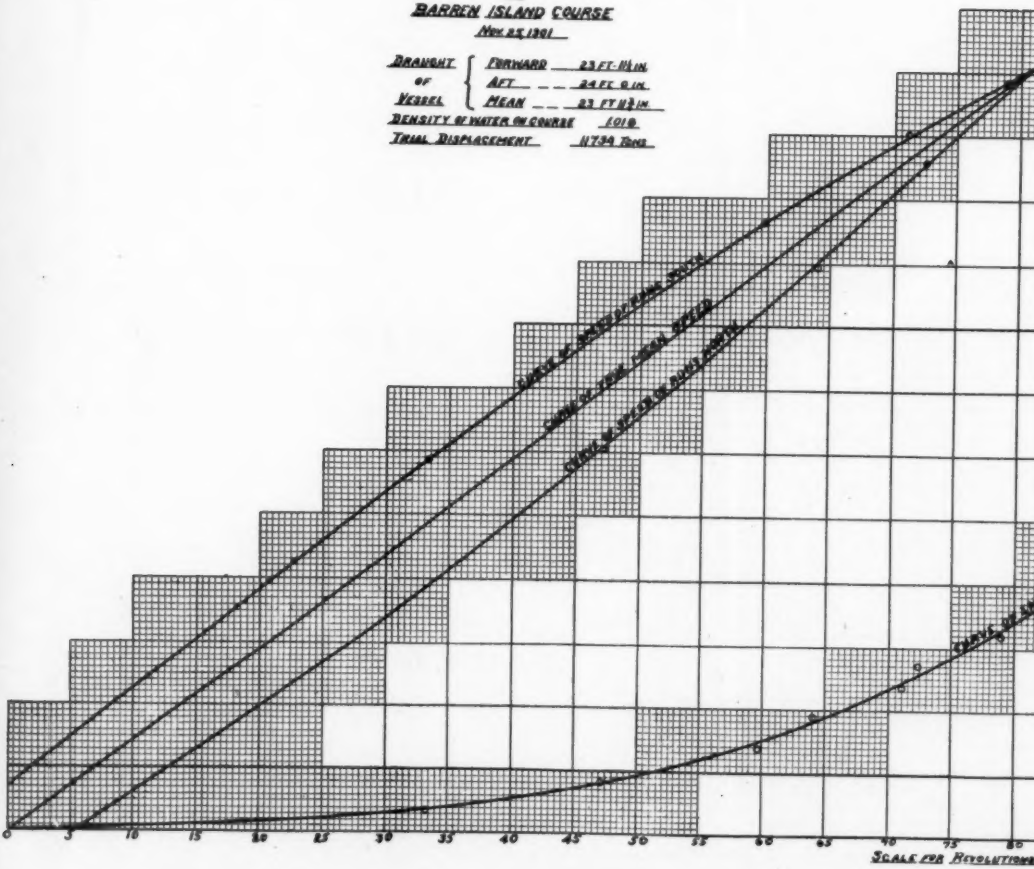
—— —U.S.S. ALABAMA —— —

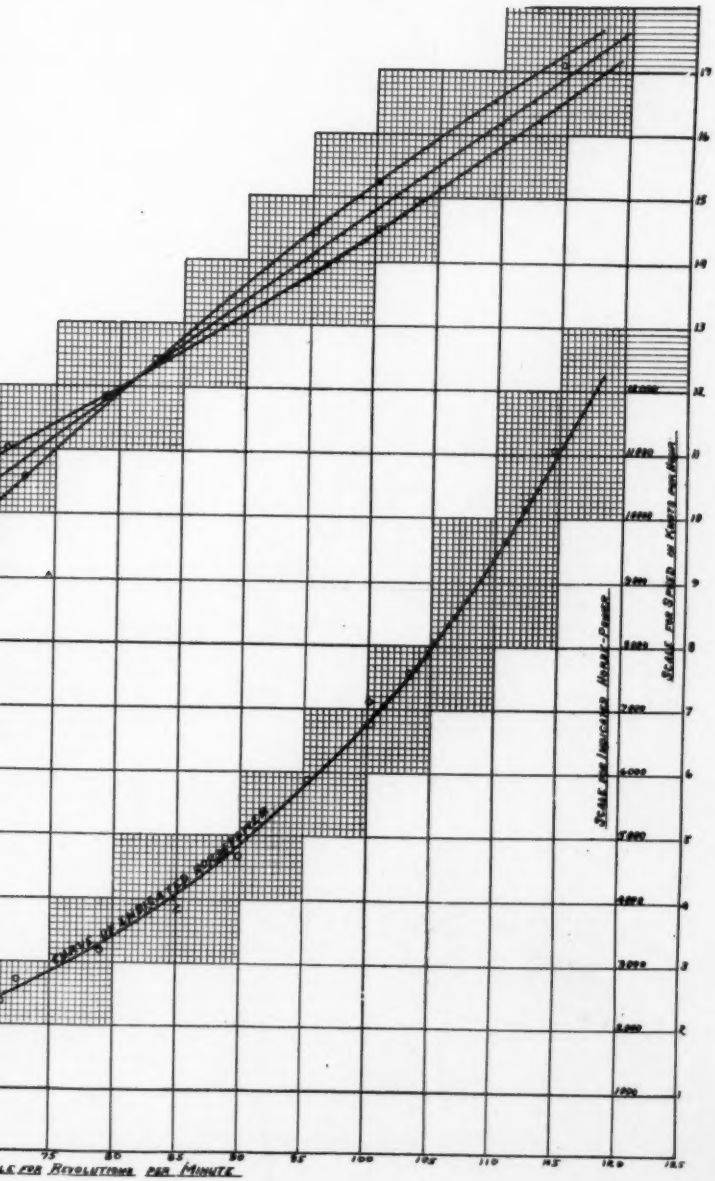
ON

BARREN ISLAND COURSE

NOV. 25 1901

DRAUGHT OF VESSEL	FORWARD	23 FT. 11½ IN.
	AFT	24 FT. 0 IN.
	MEAN	23 FT 11¾ IN.
DENSITY OF WATER ON COURSE		1019
TRIAL DISPLACEMENT		11794 Tons

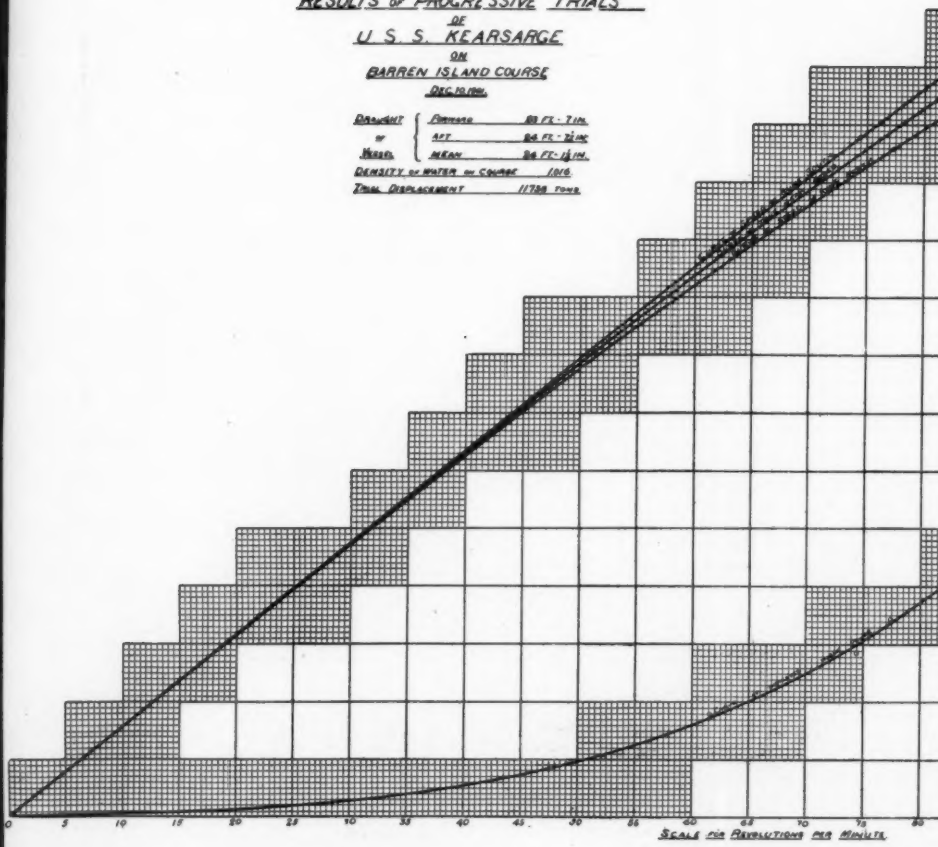


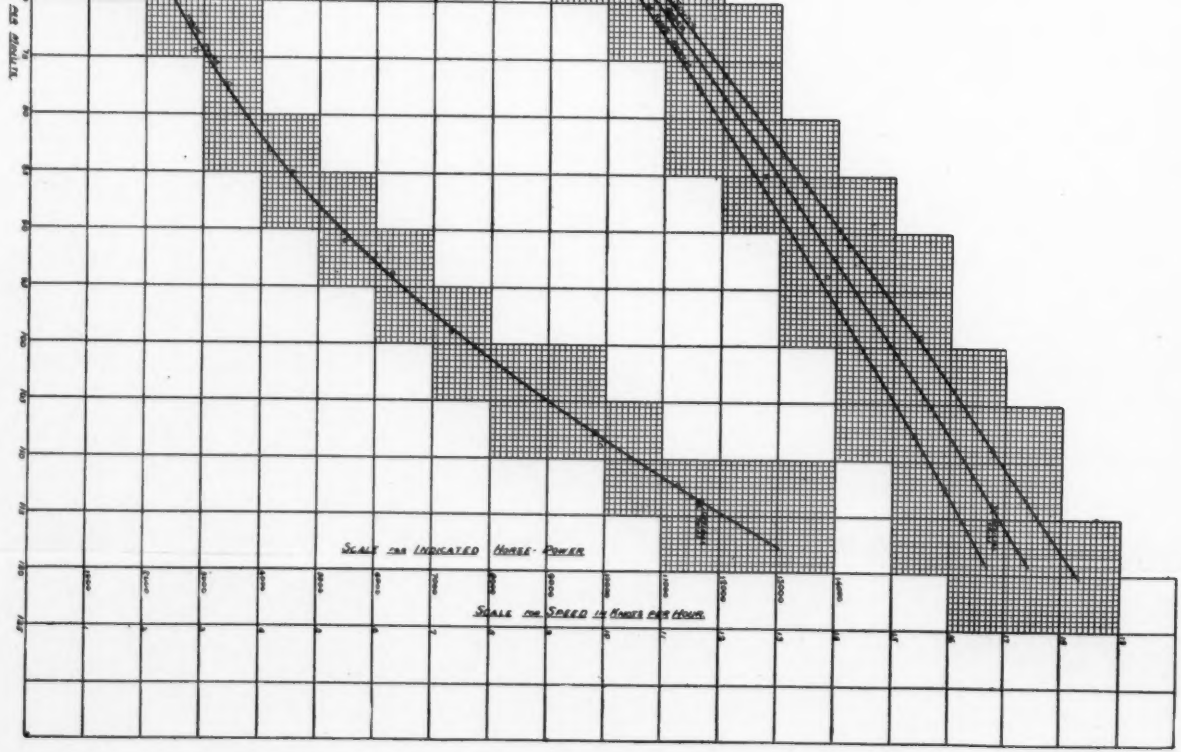

Scale for Indicated Horse-Power.
Scale for Speed in Knots per Hour.
75
80
85
90
95
100
105
110
115
120
125

APPENDIX C-K.

RESULTS OF PROGRESSIVE TRIALS OF U. S. S. KEARSARGE ON BARREN ISLAND COURSE DEC. 19, 1911.

DRAUGHT OF VESSEL	FORWARD	23 FT. 7 IN.
	AFT	26 FT. 3½ IN.
	MEAN	24 FT. 11½ IN.
DENSITY OF WATER ON COURSE		1016.
TRIAL DISPLACEMENT		11738 TONS.

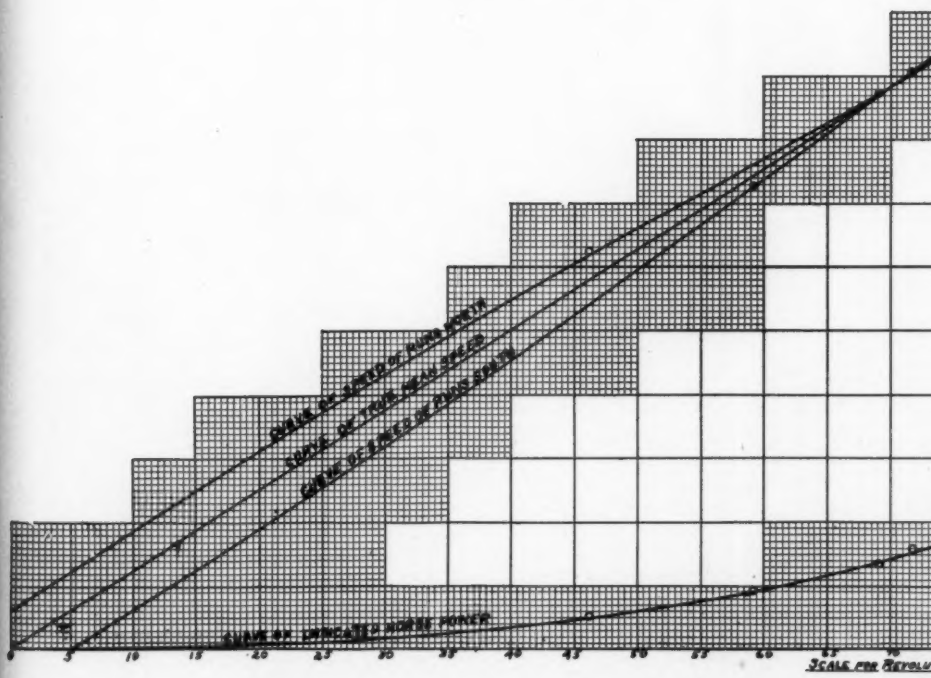


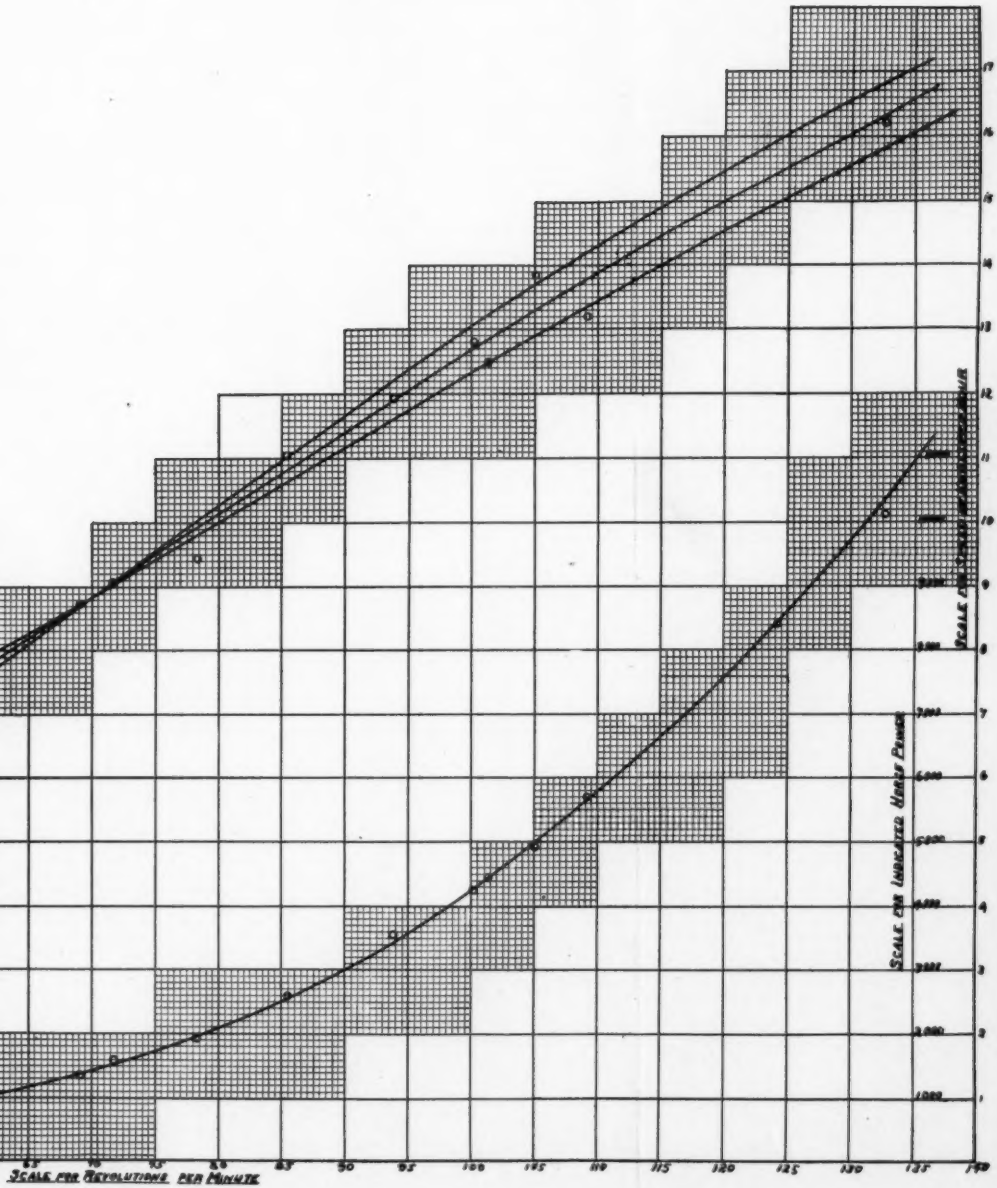

REVOLUTIONS PER MINUTE
SCALE FOR INDICATED HORSE-POWER
SCALE FOR SPEED IN MILES PER HOUR

APPENDIX C-M

RESULTS OF PROGRESSIVE TRIALS
OF
U.S.S. MASSACHUSETTS
ON
BARREN ISLAND COURSE
NOV 27 1901

DRAUGHT OF VESSEL	FORWARD	23 FT-1½ IN.
	AFT	25 FT-10 IN.
	MEAN	24 FT-11½ IN.
DENSITY OF WATER ON COURSE		1.019
TRIAL DISPLACEMENT		11685 TONS




Scale per Revolutions per Minute
Scale for Indicated Horse Power
Scale for Brake Horse Power

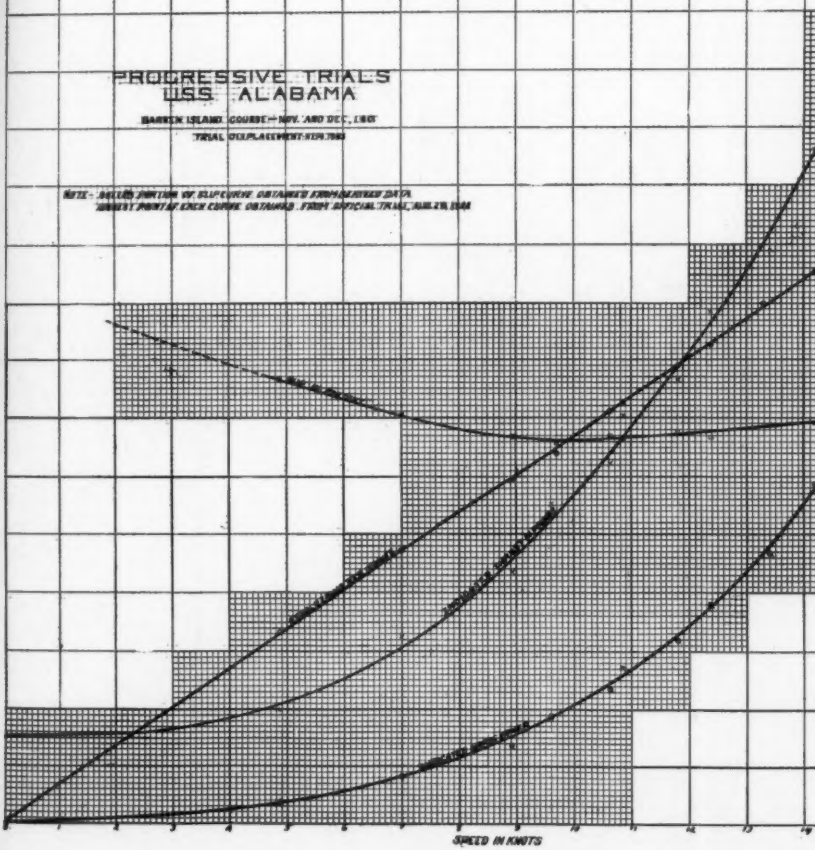
APPENDIX D-A

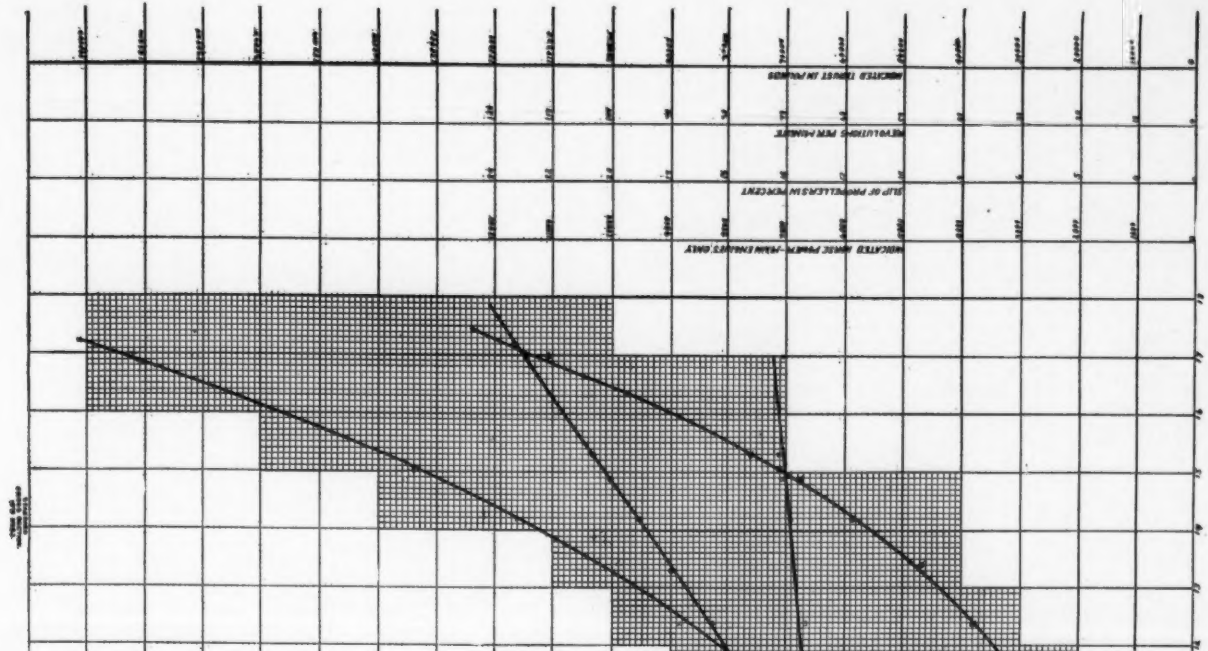
PROGRESSIVE TRIALS
USS ALABAMA

BARREN ISLAND COURSE — NOV. AND DEC., 1942

TRIAL DISPLACEMENT-[illegible]

NOTE - [illegible]



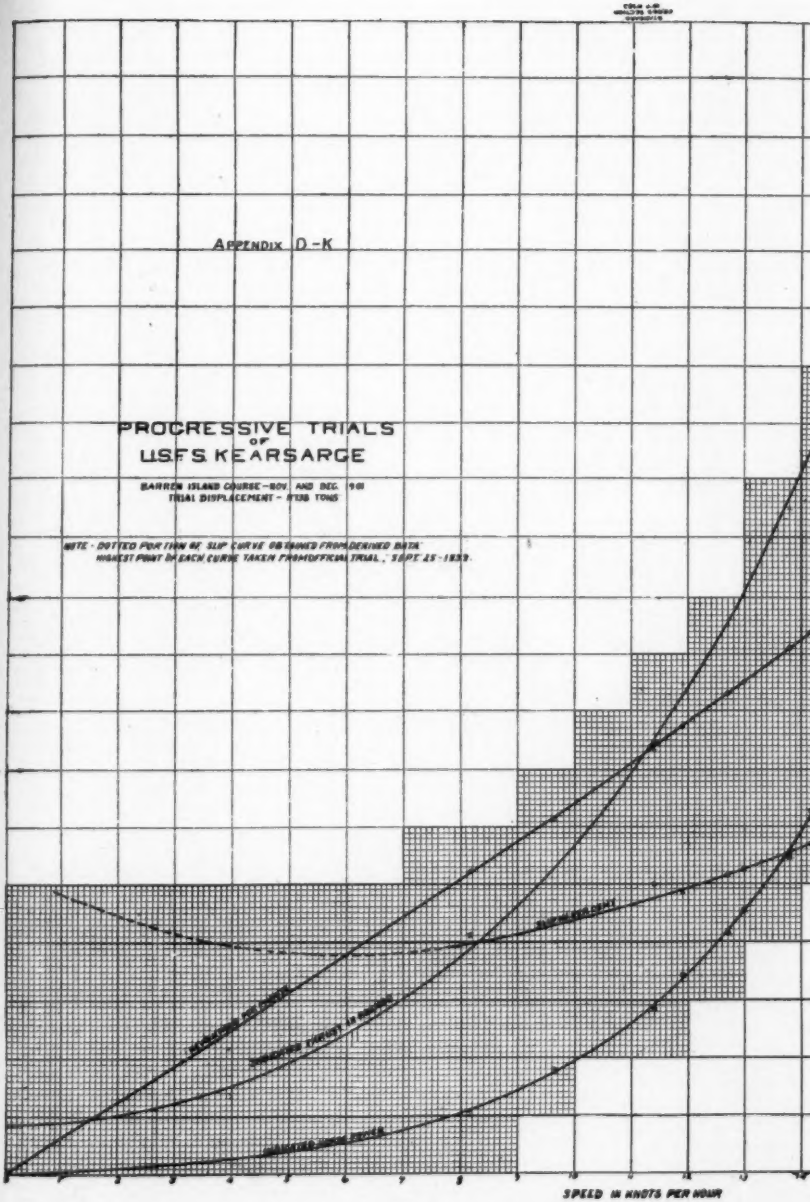


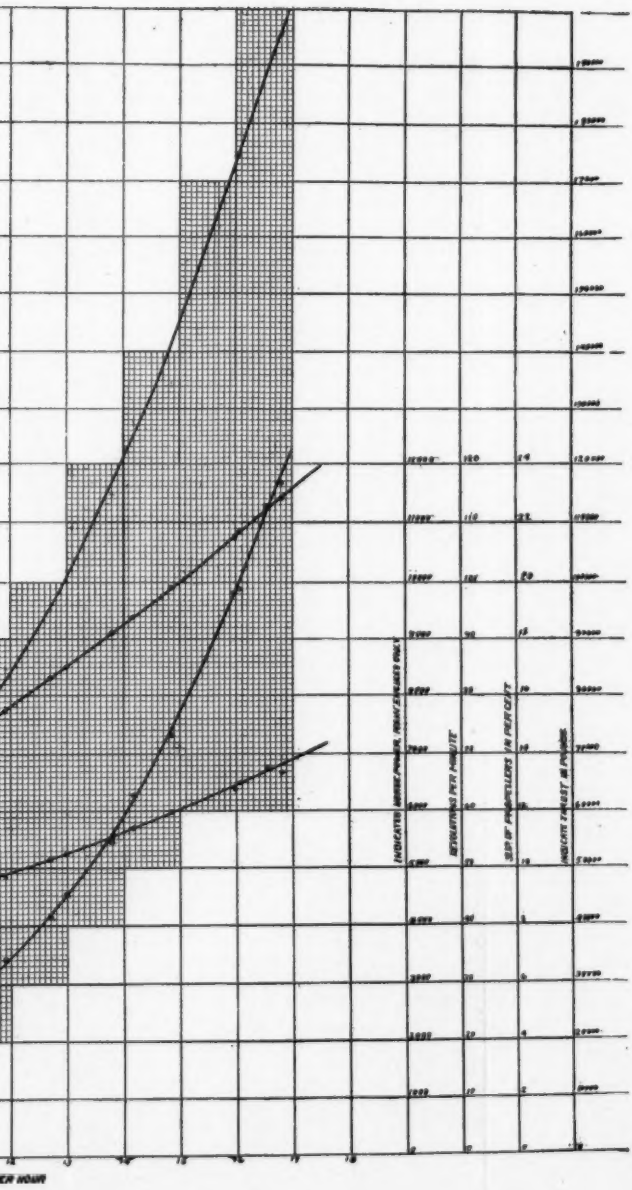
APPENDIX D-K

PROGRESSIVE TRIALS OF U.S.F.S. KEARSARGE

BARREN ISLAND COURSE—NOV. AND DEC. 1911
TRIAL DISPLACEMENT - 8788 TONS

NOTE - DOTTED PORTION OF SLIP CURVE OBTAINED FROM DERIVED DATA
HIGHEST POINT ON EACH CURVE TAKEN FROM OFFICIAL TRIAL, SEPT 25-1939.

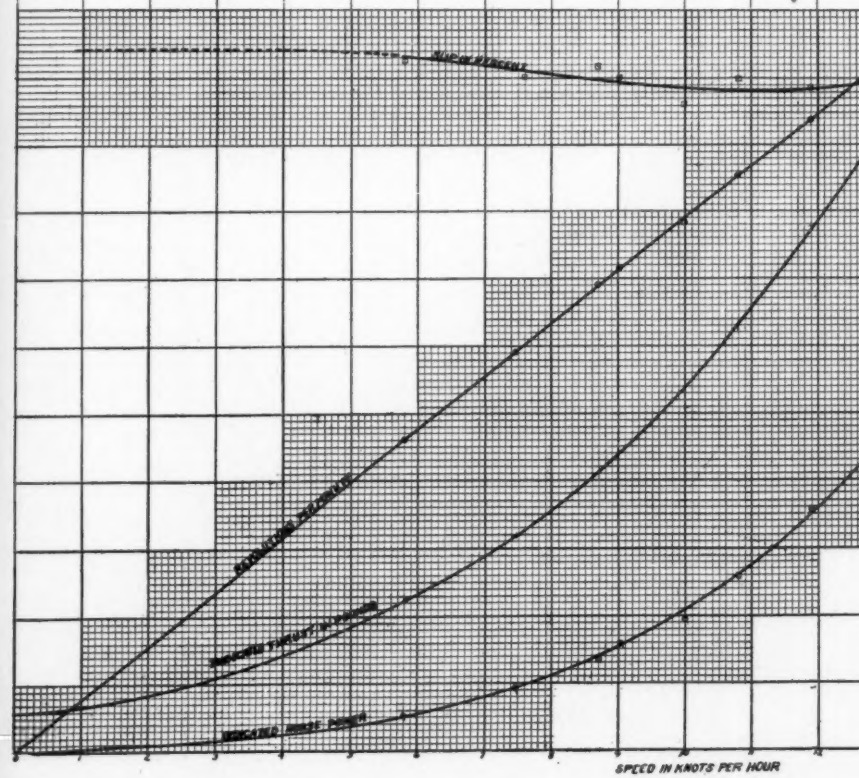


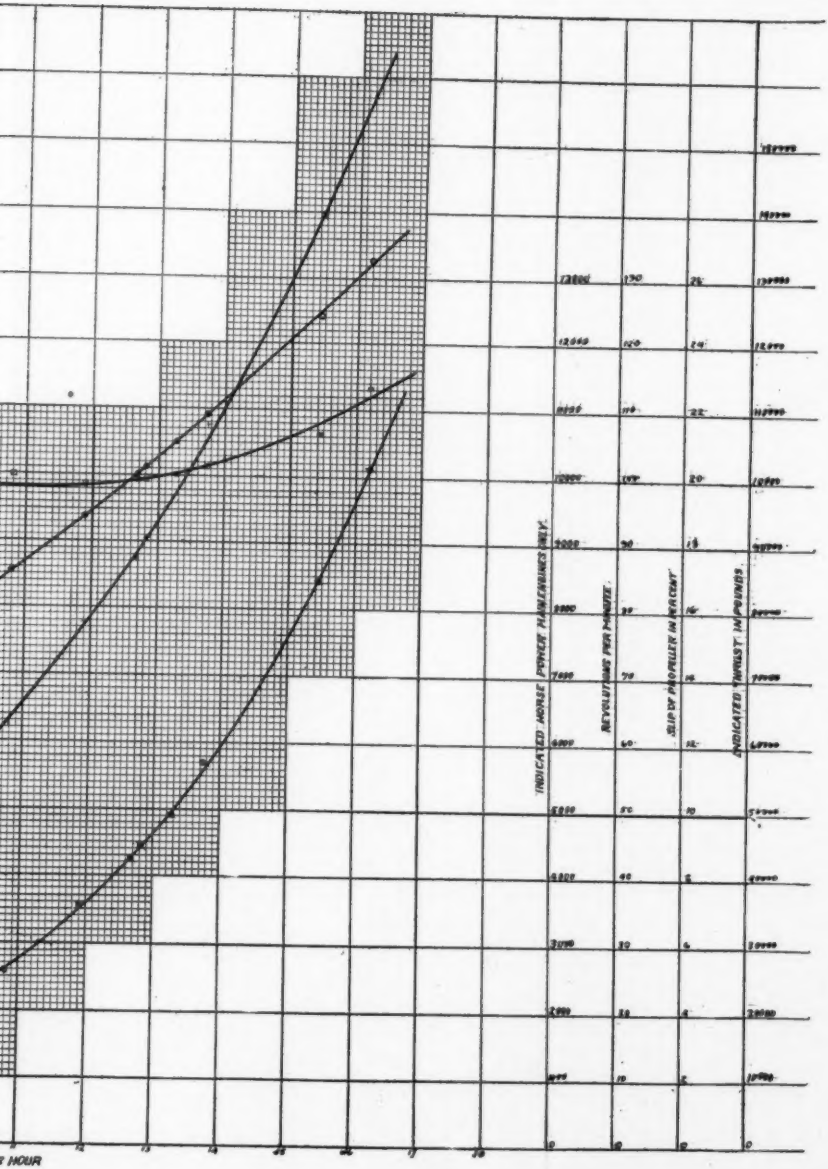

INDICATED HORSE POWER, RISE EXHAUST ONLY
REVOLUTIONS PER MINUTE
SLIP OF PROPELLERS IN PER CENT
INDICATED THRUST IN POUNDS

PROGRESSIVE TRIALS OF USS MASSACHUSETTS

SANDY ISLAND COURSE NOV. AND DEC. 1901.
TRIAL DISPLACEMENT - 10653 TONS

NOTE - DOTTED PORTION OF SLIP CURVE OBTAINED FROM DERIVED DATA
MIDWEST POINT OF EACH CURVE TAKEN FROM OFFICIAL TRIAL - APR. 25, 1896.

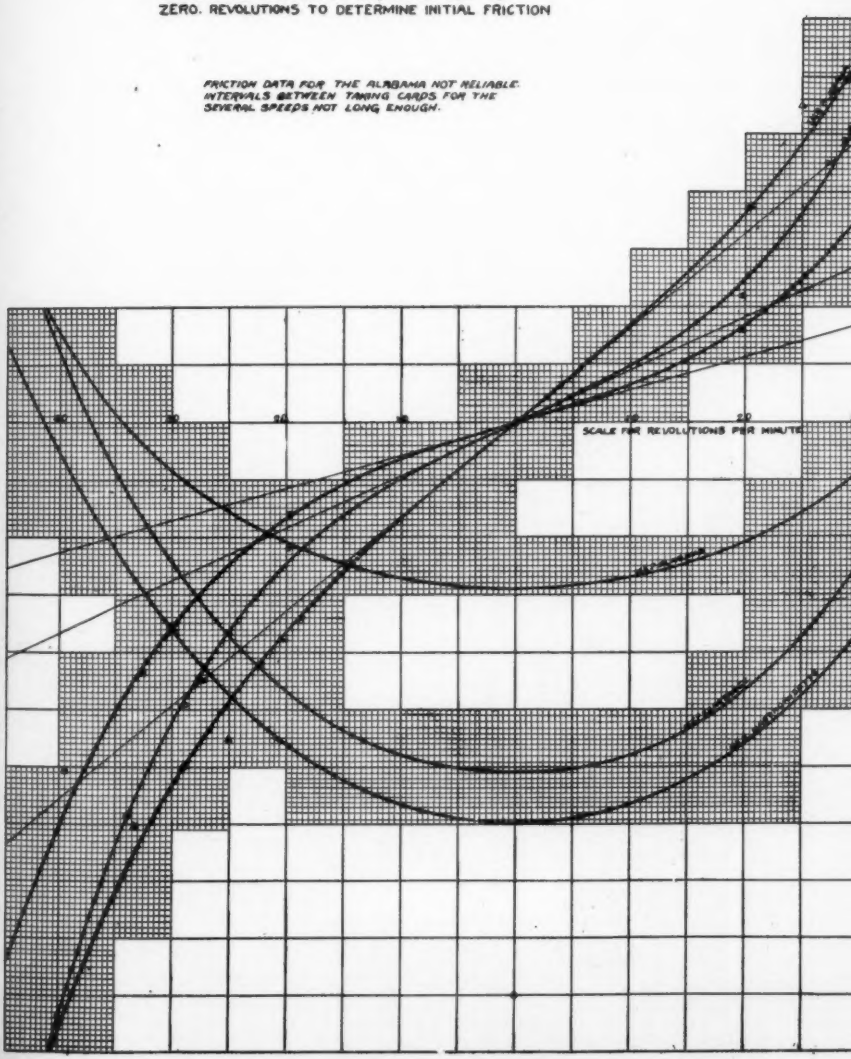


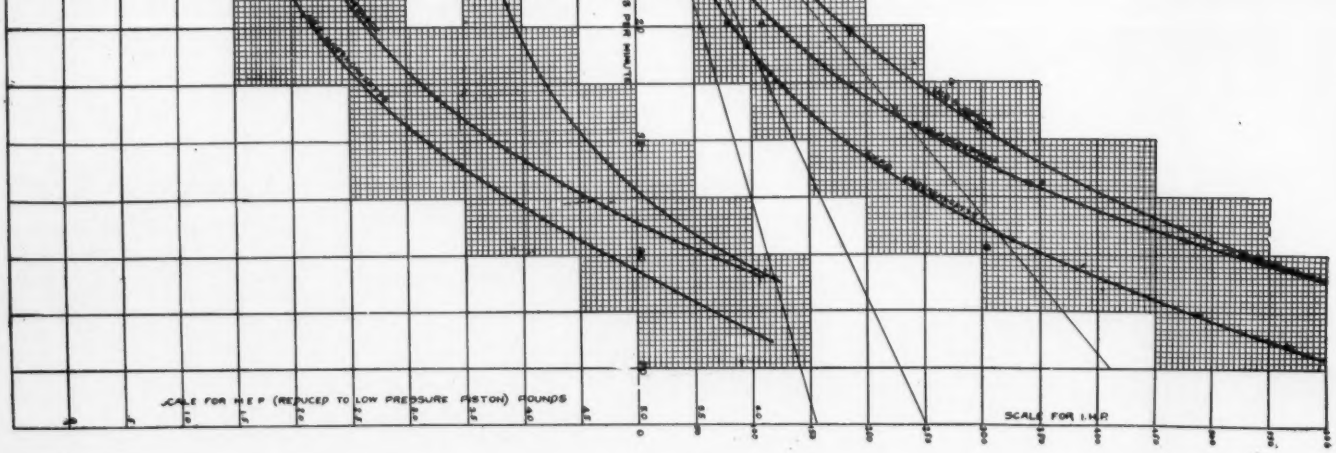

INDICATED HORSE POWER FLAMEBURNER ONLY.
REVOLUTIONS PER MINUTE.
SLIP OF PROPELLER IN PERCENT
INDICATED THRUST IN POUNDS.
PER HOUR

APPENDIX-E

CURVES OF I.H.P AND M.E.P. AT LOW SPEEDS
PLOTTED ON REVOLUTIONS AND EXTENDED TO ZERO. REVOLUTIONS TO DETERMINE INITIAL FRICTION

FRICTION DATA FOR THE ALABAMA NOT RELIABLE. INTERVALS BETWEEN TAKING CARDS FOR THE SEVERAL SPEEDS NOT LONG ENOUGH.




SCALE FOR M.E.P (REDUCED TO LOW PRESSURE PISTON) POUNDS
SCALE FOR I.H.P

Date of trial—December 10, 1901.

Place of trial—Off Barren Island, Chesapeake Bay.

Progressive trial began about 10·15 A. M., local time.

Progressive trial ended about 1·03 P. M., local time.

Before trial, at 8·35, draught forward, 23 feet 7 inches; aft, 24 feet 7¼ inches.

After trial, at ——, draught forward, ——; aft, ——.

Assumed trial conditions: Draught forward, 23 feet 7 inches; aft, 24 feet 7¼ inches.

Mean draught, 24 feet 1⅛ inches; density of water on course, 1.016—determined by hydrometer from medical department just before trial.

Trial displacement, 11,738 tons.

Tidal data from chart of course and tide tables for 1901:

H. W. on course	1·22 P. M.
L. W. on course	7·16 A. M.
Before ebb—H. W. slack on course	5·07 P. M.
Before flood—L. W. slack on course	10·36 A. M.
Maximum flood on course	0.7 knots.
Maximum ebb on course	0.8 knots.

BRIEF RECORD OF TRIAL.

Reported by Naval Constructor D. W. Taylor, at Speed Recorder.
Forward observer, Lieutenant Poyer; after observer, Lieutenant Chadwick.

No. of run.	Direction of run.	Entered course about—	Stop-watch time on course.		Nature of record from instruments.
			Min.	*Sec.*	
1	N.	10·15·30	3	47	Good.
2	S.	10·28·55	3	34¼	
3	N.	10·42	3	54	
4	S.	10·56·15	3	53½	
5	N.	11·10·30	4	20¼	
6	S.	11·26·30	4	13	
7	N.	11·41·15	4	42½	
8	S.	11·56·05	4	36½	Skipped some seconds—bad contact.
9	N.	12·09·15	5	11¼	
10	S.	12·26·05	5	5¼	Forward range connection broke during run.
11	N.	12·42·30	6	20	
12	S.	1·03·40	7	15½	

REMARKS.—Odd-numbered runs against tide at beginning. Stop-watch about five minutes slow of ship's time, seventy-fifth meridian.

WIND AND WEATHER DURING TRIAL.

Time.	Direction of wind.	Force of wind.	Condition of sea.	Bar.	Thermometer, dry bulb.
10	N. N. W.	3-4	Good many white caps.	30.08	49
11	N. N. W.	3-4	Do.	30.11	50
12	N. W.	3-4	Do.	30.14	48
1	N. W.	3-4	Do.	30.17	50

APPENDIX A-M.

DECK RECORD OF PROGRESSIVE TRIAL.

Name of vessel—U. S. S. *Massachusetts.*

Vessel undocked—November 2, 1901.

Condition of bottom when undocked—newly painted.

Painted with two coats McInnes paint, one anti-corrosive and one anti-fouling.

Itinerary from undocking to date of trial:

Alongside coal dock until November 21, 1901; November 21st, sailed for Barren Island; on November 23d, anchored at Barren Island.

Date of trial—November 27, 1901.

Place of trial—near Barren Island, Chesapeake Bay.

Progressive trial began about 9.05 A. M. local time.

Progressive trial ended about 12.35 P. M., local time.

Before trial at 7 A. M., draught forward, 24 feet 0 inches; aft, 25 feet 9½ inches.

After trial, at 2 P. M., draught forward, 23 feet 9 inches; aft, 25 feet 10½ inches.

Assumed trial conditions: Draught forward, 23 feet 10½ inches; aft, 25 feet 10 inches.

Mean draught, 24 feet 10¼ inches; density of water on course, 1.018—determined by hydrometer of medical department in water taken from course during last run.

Tidal data from chart of course and tide tables for 1901:

H. W. on course		2·04 A. M.	2·32 P. M.
L. W. on course		8·35 A. M.	
Before ebb—H. W. slack on course		5·49 A. M.	6·17 P. M.
Before flood—L. W. slack on course		11·55 A. M.	
Maximum flood on course	0.7 knots	2·39 A. M.	3·07 P. M.
Maximum ebb on course	0·8 knots	8·55 A. M.	

Maximum current strengths are taken from chart. N. W. wind had been blowing three days at time of trial.

BRIEF RECORD OF TRIAL.

Reported by Lieutenant Salisbury, at Speed Recorder.
Forward observer, Naval Constructor D. W. Taylor; after observer, Gunner McDermott. November 27, 1901.

No. of run.	Direction of run.	Entered course.	Time on course.	Nature of record from instruments.
		A. M.		
1	S.	9·05.57	3·46	Front signal did not work.
2	N.	9·24.10	4·33	Marks at end of run questionable.
3	S.	9·40.505	4·20	
4	N.	9·55.48	4·48.5	
5	S.	10·15.055	4·40.5	
6	N.	10·33.26	5·02	
7	S.	10·54.16	5·26	
8	N.	11·10.15	6·21.8	Main-battery wire disconnected a few seconds.
9	S.	11·27.43	6·37	At end of run after signal did not mark.
10	N.	11·44.195	6·53	
11	S.	12·03.595	8·15	
12	N.	12·25.23	10·35	

REMARKS.

Odd-numbered runs are against tide at beginning.

WIND AND WEATHER DURING TRIAL.

Time.	Direction of wind.	Force of wind.	Condition of sea.	Bar.	Thermometer, dry bulb.
9	N. N. W.	4	Numerous white caps.	30.43	44
10	Do.	4		30.44	44
11	Do.	4		30.48	48
12	Do.	3	Fair—no white caps.	30.50	51

WARSHIP BUILDING IN 1901.

[Reprinted from London "Engineering."]

The ships launched during the year which is now closing will form a larger addition to the British Navy than those floated in any preceding year. The thirty-two vessels floated, embracing every type from the submarine boat to the leviathan cruiser and immense battleship, make up a total displacement tonnage of 209,100 tons, which compares with 35,604 tons in the concluding year of the century. But, as we pointed out a year ago, the conditions were somewhat abnormal, many of the vessels being delayed on the stocks owing to circumstances associated with armor plate manufacture which need not be entered into here, so that it is only fair to strike a mean between the output of the two years; and from this standpoint the result is not unsatisfactory. The tonnage floated in any one period, however, is only an approximately accurate way of measuring progress; thus the total we have given is satisfactory, but it would be more reassuring if one could say that, so far as the ordering of work is concerned, the state of affairs was equally favorable for the future maintenance of naval strength.

Upon the naval programme authorized in the last session of Parliament, practically no real constructional work has been done. Three battleships and six armored cruisers were included, besides smaller craft, in the authorized additions, and of these, two battleships and five cruisers are to be given out to contract. The dockyard officials, of course, knowing the dimensions of the ships that they are to build, can make preparations; but since the contractors have not yet been asked to submit tenders, there is no chance of these vessels being commenced before next springtime. This delay is largely associated with design and the boiler question. The Boiler Committee appointed to investigate the subject have naturally had some say in the type of boiler to be

adopted, and, while they have come to a decision as regards the battleships, there is no settlement on the question of the steam generators for the cruisers.

As to these six cruisers, the Admiralty have invited the principal machinery builders to submit six alternative proposals. The cruisers, it may be remembered, are to be of the County class, of which ten are already under construction. They are designed for high speed with a large measure of armored protection; and to get twenty-three knots 22,000 horsepower has to be indicated; 1,900 tons was taken as the basis for weight—including, of course, machinery—and the prospective contractors were asked to state what weight would be necessary to get this power with cylindrical boilers, worked under the closed stokehold system of forced draft, or with hot blast, on such a system as that of Messrs. Howden or Messrs. Ellis and Eaves. To this request several of the firms, we understand, have replied that the weight of the machinery for the power desired would not fall short of 2,100 tons; or, in other words, the power possible with the tank boiler for the weight specified would not exceed 19,500 indicated horsepower. The firms are now engaged in preparing the other alternative suggestions, for installing a combination of water-tube and cylindrical boilers, different proportions of Yarrow large-tube and cylindrical, and of the Dürr and the cylindrical, having been specified. These designs will take some weeks to prepare, and the giving out of the work is thus deferred. It is, of course, important that a satisfactory system of steam generation should be adopted, but at the same time one cannot fail to realize the seriousness of the delay in construction, especially as, generally speaking, the ships of our shipbuilding programmes for the past two or three years have not in all cases been carried out within the time stipulated.

But to return to the ships launched during the year, it may be stated that from the five dockyards eight vessels, totalling 64,910 tons, have been floated. This is not an exceptionally large output when compared with normal years, although it greatly exceeds last year's subnormal production. But it is specially notable that the facilities in the dockyards for carrying out work expeditiously

have been greatly increased, Sir James Williamson, the Director of Dockyards, having with characteristic progressive spirit installed a very large number of modern machine tools; but with a greatly-increased fleet, the extent of repair work must necessarily grow, and consequently the establishments have of late years been devoted more and more to such overhaul work. During this year the dockyards have been engaged on the completion of thirteen new ships for commission, including three battleships and several cruisers, while, at the same time, over twenty vessels have undergone extensive repairs and refits, in addition to the overhauling of the ships forming the Reserve and Channel Squadrons—a programme which at once indicates the extensive work done, apart altogether from new shipbuilding; but it would be a mistake to discontinue, to any great extent, the new work undertaken, because of its educational value, and of its necessity

TABLE I.—FIGHTING VESSELS LAUNCHED.

——	No.	Tons.	Indicated horse power.	Value of ships completed.
In 1901. Dockyards	8	64,910	114,200	£4,901,200
Private yards (H. M. S.)	24	144,190	275,000	11,002,600
(foreign)	7	2,442	47,500	340,000
Total in 1901	37	211,542	436,700	16,243,800
In 1900. Dockyards	4	5,230	11,200	394,600
Private yards (H. M. S.)	17	30,374	125,800	2,531,600
(foreign)	8	25,827	42,750	1,925,000
Total in 1900	29	61,431	179,750	4,851,200
In 1899. Dockyards	6	66,900	78,000	4,901,100
Private yards (H. M. S.)	12	53,222	111,000	3,791,000
(foreign)	16	47,170	124,000	3,767,000
Total in 1899	34	167,292	313,000	12,459,100
In 1898. Dockyards	8	70,955	84,800	4,441,000
Private yards (H. M. S.)	22	70,033	168,800	4,242,000
(foreign)	18	52,365	144,250	3,480,000
Total in 1898	48	193,353	397,850	12,163,000

to keep the men fully employed when repair work is slack, as occurs at seasons; besides, without new construction, the standard of excellence of workmen necessary for repairs might not be so easly maintained, and it is subject for consideration whether in the future it might not be desirable to send ships for extensive overhaul to their original builders, rather than to diminish the amount of original constructive work carried on in the dockyards. This course is preferable to adding largely to the number of hands now employed in the dockyards. It will also tend to educate private firms in this important class of repair work. That will be invaluable in times of emergency, especially when ships might be disabled at or near our large shipbuilding and repairing centers.

From private yards there have been launched twenty-four British warships, of 144,190 tons, which is greater than in any year during the past decade—if, indeed, it has ever been excelled in the history of warship building. It is double the output of 1898, compares with 53,222 tons in 1899, and is almost five times the total of last year. Similarly, the horsepower is much greater, but the difference here is not quite so marked, owing to the fact that comparatively few torpedo-boat destroyers are included this year; and when it is noted that the fastest battleship has barely 1.3 H.P. per ton displacement, and the cruiser 2 H.P. per ton, while the destroyer has 20 H.P. per ton, this difference in the ratios of increase of power and of tonnage will be easily understood.

Of the thirty ships launched for the British Fleet, six were battleships of the same class, the prototype being the *Duncan*. These ships were built respectively, the *Albemarle* at Chatham, with engines by the Thames Iron Work Company; the *Montagu* at Devonport, with engines by Messrs. Laird Brothers, Limited, Birkenhead; the *Duncan* and *Corwallis* by the Thames Company; the *Russell* by Palmer's Company, of Jarrow-on-Tyne; and the *Exmouth* by Messrs Laird. These battleships, which were ordered two years ago, and should all be completed within the three years, are remarkable for their speed—19 knots—which is attained by engines of the four-cylinder triple-expansion type of

18,000 H.P. The vessels are 405 feet long, 75 feet 6 inches beam, and their displacement is 14,000 tons when they are drawing 26 feet 6 inches. They are thus lighter by 1,000 tons than the six battleships which preceded them, due largely to the adoption for broadside armor of Krupp steel of 7 inches in thickness, instead of Harvey's steel of 9 inches. They have four 12-inch guns and twelve 6-inch guns, but in the new battleships to be laid down this year the important change is made of introducing, in addition to the 12-inch guns, four weapons of 9.2 inches caliber, one mounted at each corner of the citidel; and this improvement in gun power, associated as it is with other qualities involves an increase in displacement to 16,500 tons.

Ten more of the new ships launched during 1901 are armored cruisers. Two of them, the *Euryalus*, launched at Messrs. Vickers' works at Barrow-in-Furness, and the *Bacchante*, launched and passed through her speed trials by Messrs. John Brown and Co., of Clydebank, belong to the *Cressy* class, numbering six in all, of 12,000 tons, 21,000 indicated horse power, and 20 knots speed. Four others constitute what is known as the *Drake* class; the prototype was launched at Pembroke and is having her engines fitted on board by Messrs. Humphreys, Tennant & Co., London; the *Good Hope* was built by the Fairfield Company, and will be delivered at Portsmouth Dockyard this month; the *Leviathan* is being rapidly brought forward for delivery at Messrs. Brown's works at Clydebank, as is also the *King Alfred*, built by Messrs. Vickers, Sons and Maxim, at Barrow-in-Furness. This type of ship, constitutes an improvement on the *Powerful* and *Terrible*, the important change being in giving them a broadside belt of 6 inches thick, while their speed has been increased to 23 knots, necessitating the adoption of machinery of 30,000 indicated horsepower, the displacement being 14,100 tons. The other four armored cruisers launched during the year—the *Bedford*, by the Fairfield Company; the *Monmouth*, by the London and Glasgow Company; the *Kent*, at the Portsmouth Dockyard, with engines by Messrs. Hawthorn, Leslie & Co., Newcastle; and the *Essex*, at the Pembroke Dockyard, with engines by Messrs. Brown, of

Clydebank—belong to the new County class, in which, on limited displacement, the high speed of 23 knots is attained in combination with a side armor of Krupp hardened steel 4 inches in thickness. The County vessels launched will have fourteen 6 inch quick-firing guns, but in the six vessels to be laid down shortly a change will be made by the fitting of two 7.5-inch guns and ten 6-inch weapons, the higher ballistics of the 7.5-inch weapons compensating for the lesser number of weapons installed.

The other vessels launched in 1901 are of small type, but nevertheless of considerable interest. From the Sheerness Dockyard there were floated three sloops, named *Fantome*, *Odin* and *Merlin;* these are of 1,070 tons displacement, and have engines of 1,400 horsepower, but they are specially interesting because in them the Boiler Committee are making exhaustive trials as to the relative merits of the Belleville, Babcock & Wilcox, Niclausse and Dürr steam generators. Messrs. Yarrow completed two gunboats—*Teal* and *Moorhen*—which were built in sections, so as to be easily transported and fitted up on the waters of some of the distant outposts of the Empire; they are boats of 160 feet in length, and 180 tons displacement, with a draught of only 2 feet 3 inches, and with their engines of 800 horsepower attain a speed of 13 knots. Messrs. Thornycroft completed four torpedo boats of 25 knots speed, which are noteworthy because in their design greater heed has been paid than in previous vessels of this class to those qualities which will enable the vessels to weather heavy seas and maintain their high speed under adverse conditions. This firm have recently received an order for four more vessels of the same class. Messrs. John Brown & Co., Clydebank, launched a 32-knot destroyer—the *Arab*—and Messrs. Doxford, of Sunderland, the *Success*, of 30 knots speed. The five submarine boats floated by Messrs. Vickers, Sons and Maxim, at Barrow, make up the thirty-two vessels included on our list.

As to how this compares with the production of previous years, some idea can be formed by a reference to Table II, showing the tonnage launched from Royal and private yards during the past twelve years. The nearest approximation to the 209,100 tons of

TABLE II.—TWELVE YEARS' PRODUCTION OF BRITISH NAVY SHIPS.

Year.	Dockyard.		Private yard.		Total.	
	No.	Tons.	No.	Tons.	No.	Tons.
1890	8	22,520	13	42,475	21	64,995
1891	8	68,100	10	39,150	18	107,250
1892	9	50,450	13	90,750	22	141,200
1893	9	32,400	5	1,919	14	34,319
1894	8	26,700	19	4,825	27	31,525
1895	8	70,350	28	66,412	36	136,762
1896	9	70,970	26	36,515	35	108,485
1897	4	31,885	22	34,111	26	65,996
1898	8	70,955	22	70,033	30	140,988
1899	6	66,900	12	53,222	18	120,122
1900	4	5,230	17	30,374	21	35,604
1901	8	64,910	24	144,190	32	209,100
Totals...	89	581,370	211	613,976	300	1,195,346

this year is the 141,200 tons of 1892, which was also a large battleship year. The average, it will be seen, is about 100,000 tons, and from this point of view the output of this year is certainly very satisfactory. The distribution of work amongst the naval yards is indicated on Table III. Here it will be seen that this year's output has been exceeded in five years since 1890; and that, too, notwithstanding that the tonnage credited to 1900 is so very small. Several ships already launched are approaching completion at the dockyards, and on them a large staff of men are at work. Two battleships will probably be launched in March next—the *Queen*, at Devonport; and the *Prince of Wales*, at Chatham—so that they are thus likely to be afloat within one year of the "formal" laying of the keel. The *Suffolk*—an armored cruiser—is also likely to be launched from Portsmouth about the same time; but the *Cornwall*, a vessel also of the County class, building at Pembroke, will not be floated until much later in the year. Two second-class cruisers are well advanced on the stocks—the *Challenger*, at Chatham, and the *Encounter*, at Devonport—the former of which is to be engined and fitted with Babcock and Wilcox boilers by the Wallsend Company, and the latter will have Dürr steam generators, while the *Suffolk* and *Cornwall* will have respectively Niclausse and Babcock and Wil-

cox boilers. Thus, in a short time practical experience will be obtained as to the relative merits at sea of several types of water-tube generators. The vessels we have named exhaust the list so far as ships on the stocks in the dockyards are concerned, and we have already referred to the ships about to be laid down.

One regrettable feature indicated on Table I is the diminution of warships built in this country for foreign powers. For several years this has been a decreasing quantity, and this year only torpedo-boat craft fall to be included; the tonnage is almost inappreciable when compared with the 50,000 and 60,000 tons of past years. The vessels included this year, built by Yarrow, Thornycroft, and Laird, are principally for Japan, and, moreover, at the present moment there are practically no large ships building for foreign navies.

During the year fourteen new ships for the Navy were passed through their contract trials, in addition to twelve new torpedo-boat destroyers, four torpedo boats, and two of the older destroyers after being re-boilered, making a total of thirty-two vessels in all; while last year the number was twenty-nine, and if the fighting worth of the ships be considered, there is even a greater preponderance. This year's list includes six battleships, against two last year; four armored cruisers, against one armored and one protective-deck cruiser of the first class last year; while in 1899 we had only three battleships and two first-class cruisers, although the number of small craft brought the total number of vessels up to thirty-seven. This year's work of the engineering

TABLE III.—THE PRODUCTION FROM EACH NAVAL YARD.

Yard.	1901.		1900.		1899.		Average for twelve years.
	No.	Tons.	No.	Tons.	No.	Tons.	Tons.
Portsmouth	1	9,800	1	2,200	1	15,000	13,636
Chatham	1	14,000	...	...	2	17,200	13,290
Devonport	1	14,000	...	...	2	30,000	9,299
Pembroke	2	23 900	...	...	1	4,700	9,876
Sheerness	3	3,210	3	3,030	...	...	2,430
Totals	8	64,910	4	5,230	6	66,900	50,531

department under Sir John Durston, K. C. B., has therefore been very important, and it is a striking fact that, with few exceptions, the programme of trials for almost every ship has been carried through without any of the difficulties which marked the tests of the earlier high steam-pressure machinery.

This advance in thermo-dynamics, as we have from time to time pointed out, brought with it, as is always the case with big steps in progress, many little problems, which, however insignificant, militated against immediate success. But these have been tackled with a pluck which is sometimes lost sight of in the volume of criticism which has become the fashion of the period when pessimism is abroad in the land, and is ill-informed if not suggestive of wisdom after the affair. But this is by the way. Some of the changes made were reviewed by Mr. James McKechnie in his paper at the Institution of Mechanical Engineers, and in other directions improvements are always being considered and adopted. The engine stroke is likely to be lengthened in the future; the condensers, in the case of large engines, are being divided—giving practically four for twin-engines—which enables frequent inspection and overhaul, to provide against leaky condenser tubes, with the consequent increase in salinity in the feed-water, while good results in the way of economy accrue from the passing of the exhaust from simple or compound auxiliary engines to the low-pressure receiver of the main engine, or its utilization for distillers and evaporators.

The list of results we give on Table IV is interesting from another point of view, as it includes the first installation of Babcock and Wilcox boilers, other than those experimentally adopted in the *Sheldrake;* and this adoption, it is fair to note, was decided upon before the Boiler Committee was appointed. The *Sheldrake* trials revealed several disadvantages which were overcome, and the result in the end has proved eminently satisfactory. Again, the *Niclausse* boiler was also ordered for a sloop before the appointment of the Committee—facts which suggest that the Department was not altogether oblivious to the possible advantages of other systems than the Belleville, although domi-

nated by the imperative cry for uniformity which has for years been influencing naval construction, and not without reason.

And it is not without interest to note here the extent of other systems of boilers than the Belleville adopted for other than small craft—*i. e.*, for battleships and first and second-class cruisers. Babcock and Wilcox boilers are being used for four battleships, although in one case two-thirds of the power will, perhaps, be maintained from cylindrical boilers; and in one armored cruiser, the *Cornwall*, and a second-class cruiser, the *Challenger*, the total power from this type of steam generator already provided for being thus about 100,000 indicated horsepower, excluding the boilers in two sloops. The Niclausse boiler is being fitted to two armored cruisers, each of 22,000 indicated horsepower, as well as to two sloops. There is no mention of this type of generator in connection with the new vessels soon to be given out, but it is probable that the Admiralty will purchase a small boiler of this type exhibited at the Glasgow Exhibition with the view of making exhaustive tests in a launch. The Dürr boiler is being fitted to a second-class cruiser of 12,500 indicated horsepower, and experimentally to the *Medusa*, and a Yarrow large-tube boiler to the *Medea*. It is thus evident that, however destructive has been the criticism of the committee on the Belleville boiler—and a report soon to be issued on the *Hyacinth* trials will, it is said, prove their case—they are yet apparently far from being in a position to name the best boiler available; they have made the pronouncement that it must be of the water-tube type.

But to return to the steam trials of the year, Table IV gives the mean results for all the large vessels, and Table V for torpedo craft. It is scarcely necessary to warn our readers against deductions from comparisons of the results. There is no doubt that careful workmanship is conducive to economy: with watchfulness in screwing tubes and tapping or chasing junction boxes, much may be done to prevent leakage. Again, in the fitting of the casing plates, for instance, the loss by heat radiation may be mimimized. Other factors, however, are operative to influence results, and in the absence of elaborate data it is not possible to indicate why the coal consumption, say, of the *Irresistible*, should

TABLE IV.—RESULTS OF OFFICIAL STEAM TRIALS MADE DURING 1901 BY NEWLY CONSTRUCTED BRITISH WARSHIPS.

Name of ship.	Type.	Builders of ship.	Makers of machinery.	Length of ship in feet.	Displacement.	Type of boilers.	Heating surface.	Grate area.	Thirty hours' coal-consumption trial.			Thirty hours' coal-consumption trial at higher power.			Full-power trial.		
									Indicated H.P.	Speed.	Coal per indicated H.P. per hour.	Indicated H.P.	Speed.	Coal per indicated H.P. per hour.	Indicated H.P.	Speed.	Coal per indicated H.P. per hour.
					tons.		*sq. ft.*	*sq. ft.*		*knots.*	*lbs.*		*knots.*	*lbs.*		*knots.*	*lbs.*
Implacable	Battleship	Devonport	Laird Brothers	400	15,000	Belleville	37,164	1190.47	3179	11*	1.95	11,853	16.75*	1.65	15,262	18.22†	1.87
Bulwark	Ditto	Ditto	Hawthorn, Leslie & Co.	400	15,000	Ditto	37,160	1170	3174	11.2*	1.78	11,755	16.83*	1.80	15,353	18.15†	1.83
Formidable	Ditto	Portsmouth	Earle's Shipbuilding Company	400	15,000	Ditto	37,160	1170	3281	11.5†	2	11,623	17.156†	1.89	15,552	18 13†	1.80
Irresistible	Ditto	Chatham	Maudslay, Son, and Field	400	15,000	Ditto	37,120	1170	3243	11.76*	2.40	11,626	17.5*	2.09	15,603	18.2*	1.97
Albion	Ditto	Thames Iron Works	Ditto	390	12,950	Ditto	33,799	1072	2772	11.2*	2.17	10,809	16.8*	1.81	13,885	17.8*	2.04
Vengeance	Ditto	Vickers, Sons, and Maxim	Vickers, Sons, and Maxim	390	12,950	Ditto	33,770	1050	2885	11.35*	1.69	10,387	17.49*	1.51	13,852	18.5*	1.72
Sutlej	First-class cruiser	J. Brown & Co.	J. Brown & Co.	440	12,000	Ditto	51,768	1658.5	4641	14.133†	1.99	16,602	20.628†	1.90	21,261	21.775†	2.36
Bacchante	Ditto	Ditto	Ditto	440	12,000	Ditto	51,500	1650	4624	13.6*	1.80	16,445	20.6*	1.75	21,520	21.7*	1 70
Aboukir	Ditto	Fairfield Company	Fairfield Company	440	12,000	Ditto	51.577	1650	4597	14.4*	1.90	16,274	20.2*	1.77	21',375	21.6*	1.84
Hogue	Ditto	Vickers, Sons, and Maxim	Vickers, Sons, and Maxim	440	12,000	Ditto	51,500	1650	4738	13*	2.09	16,456	20.15*	2.05	21,432	22.06†	2.06
Pandora	Third-class cruiser	Portsmouth Yard	Portsmouth Yard	300	2,200	Thornycroft	21,152	355 2	3644	16.7*	2.11	...	...	...	5218 n.d. 7331 f d.	19.185*	2.33
Mutine	Sloop	Laird Brothers	Laird Brothers	180	980	Belleville	4,030	135.7	329.9	8.1*	1.86	1044.7	12.2*	1.72	1490.7	14.55*	1.63
Rinaldo	Ditto	Ditto	Ditto	180	980	Ditto	4,030	135 7	312.7	8.8*	1.90	1030 0	13*	1.60	1434.9	13.5*	1.61
Espiegle	Ditto	Sheerness	Wallsend Engineering Company	185	1,070	Babcock and Wilcox	4,040	143.9	337.4	10*	1.53	1032.6	13.5*	1.54	1416.8	13.5†	1.70

* Log. † Millimeters.

be 2.4 pounds, as compared on a similar trial with the 1.78 pounds of the *Bulwark*. The four ships at the top of the list, Table IV, belong to a new class, of which two others are being completed—named *London* and *Venerable*. There is marked uniformity in the power developed on each trial, the variation in the low-power trial being between 3,174 and 3,281, and in the 75 per cent. power trial between 11,623 and 11,853, while in all cases the full power was exceeded by 200 to 600; but, after all, these variations are almost within the margin of error of the indicator. The power works out to 13 I.H.P. per square foot of grate, while 2½ square feet of heating surface has been allowed per unit of power, the power being equal to over 11 I.H.P. per ton. But these results are to be excelled in our later battleships where it has been considered desirable to increase the speed from 18 to 19 knots. And in this connection it is interesting to note the striking similarity in the speed of these four ships—the variation is betweeen 18.13 and 18.22 knots. This is got from a power equal to the displacement tonnage.

The *Albion* and *Vengeance* belong to the *Canopus* class, in which an effort was made to produce a medium-sized battleship; the difference when compared with their predecessors being that 6-inch Harveyized armor was used on the broadside instead of 9-inch; now 7-inch Krupp steel is regarded as sufficient, but a wider area has to be protected, so that size and displacement go on increasing. Of these six ships, the *Vengeance* has the best record for coal consumption. On the low-power trial the rates were: *Vengeance*, 1.69 pounds; *Goliath*, 1.73 pounds; *Canopus*, 1.82 pounds; *Ocean*, 1.84 pounds; *Glory*, 2.15 pounds; and *Albion*, 2.17 pounds. On the trial at about 16,000 indicated horsepower the *Vengeance* was run for 1.51 pounds per unit of power, and the other ships ranged up to 1.81 pounds, while on the full-power trial the *Glory* returned 1.58 pounds, the *Vengeance*, 1.72 pounds, the *Albion* again topping the score at 2.04 pounds. The speed anticipated in design was 18¼ knots; and all of them proved capable of doing from 18.4 to 18.5 knots. The ratios of power to surface and weights are in this case about the same as with the *Formidable* class.

TABLE V.—TRIALS OF TORPEDO-BOAT DESTROYERS AND TORPEDO BOATS DURING THE YEAR 1901.

Name of shipbuilder and engineer.	Name of vessel.	Approximate displacement.	Type of boiler.	Grate area.	Tube surface.	Indicated horsepower.	Speed in knots.	Pounds of coal per I.H.P. per hour.
				sq. ft.	*sq. ft.*			
Laird	*Express*	427	Laird's	310	17,020	(*a*) 8722	30.916	2.29
						(*b*) 8577	31.021	...
	Lively	332	"	202	12,000	(*a*) 6456	30.278	2.38
						(*b*) 6309	30.111	...
	Sprightly	332	"	202	12,000	(*a*) 6437	30.032	2.502
						(*b*) 6456	30.102	...
Palmers	*Myrmidon*	345	Reed's	257.8	13,498	(*a*) 6601	30,134	2.2
						(*b*) 6313	30,229	...
	Kangaroo	346	"	257.8	13,498	(*a*) 6488	30.184	2.26
						(*b*) 6486	30.03	...
	Syren	353	"	257.8	13,498	(*a*) 6665	29.764	2.49
						(*b*) 6708	30.000	...
Vickers, Sons and Maxim	*Vixen*	360	Normand	234	12,000	(*a*) 6758	29.389	2.41
						(*b*) 6961	29.797	...
Hawthorn, Leslie & Company	*Greyhound*	340	Yarrow	252	13,200	(*a*) 6368	30.157	2.345
						(*b*) 6141	30.337	...
	Roebuck	335	"	252	13,200	(*a*) 6537	30.346	2.38
						(*b*) 6591	30.181	...
	Racehorse	335	"	252	13,200	(*a*) 6292	30.179	2.378
						...	...	...
Earles	*Bullfinch*	320	Thornycroft	237	13,050	(*b*) 5886	Not taken	...
	Dove	324	"	237	13,050	(*b*) 6059		...
Yarrow	*Charger**	...	"	177.6	8,520	3746	25.331	...
	*Hasty**	...	"	177.6	8,520	3822	25.592	...
Thornycroft	*No. 98*, first C. T. B.	181	"	104	6,080	(*a*) 2883	24.982	2.44
						(*b*) 2975	25.523	...
	No. 99, first C. T. B.	185	"	104	6,080	(*a*) 2667	25.069	2.59
						(*b*) 2739	24.938	...
	No. 107, first C. T. B.	184	"	104	6,080	(*a*) 2823	25.053	2.325
						(*b*) 2899	25.206	...
	No. 108, first C. T. B.	182	"	104	6,200	(*a*) 2876	25.359	2.009
						(*b*) 2783	25.446	...

* Trials after re-boilering by Messrs. Earles. (*a*) Three hours' full-power coal-consumption trial. (*b*) Three hours' full-speed trial.

The four armored cruisers on the list belong to the *Cressy* class; the prototype was tried last year, and gave results equal to the average of the four on the list. The remaining vessel of the class, the *Euryalus*, has been delayed by *force majeure*. They were designed to steam 21 knots, but, as a matter of fact, they have exceeded this, ranging up to 22.06 knots in the case of the *Hogue*, the variations of the five tried being between 21.6 and 22 knots—a realization of design which has even been characteristic of Sir William White's ships. The power necessary to get this result—about 21,400 I.H.P. —works out to 1.19 I.H.P. per ton; but for the 23-knot cruisers now building this ratio has had to be increased. The *Pandora* belongs to the "P" class, of which eleven have been built, and all have now passed through their trials. They have various types of small-tube or express boilers, in which forced draft on the closed-stokehold system is applied; and to get the power of 7,300 I.H.P from machinery weighing about 176 tons, an air pressure of from 2¾-inches to 3¼-inches had to be resorted to, and this power is at the rate of over 40 I.H.P. per ton, 20 H.P. being got per square foot of grate. The three sloops do not call for much comment; the trials were not extensive enough to enable any comparison between the boiler system to be made.

Turning now to the Table of trial results of torpedo craft, including eighteen vessels, while last year the number was fifteen; but this almost completes the number of vessels in hand; and in view of the appointment of a committee to inquire into the strength design of these vessels, it is not improbable that the ordering of the ten boats already authorized will be delayed. The committee originated in the unfortunate disaster to the *Cobra*, fitted with Parson's turbines, which gave such satisfactory results in respect of speed alike in the *Cobra* and *Viper*. They have not been approached yet by vessels with reciprocating engines. Three firms essayed to excel 32 knots; but the *Albatross* was last year accepted at 31.55 knots for 7,732 I.H.P. and 2.26 pounds coal consumption—the latter a splendid result; this year the *Express* has been accepted at 31.021 knots for 8,577 I.H.P. and 2.29 pounds

coal consumption; the Clydebank high-speed boat, the *Arab*, has not yet been subjected to her official trials. It will be seen that in only one case, in Table V, did the coal consumption exceed the 2½ pounds per unit of power stipulated for in the specification; it ranged from the 2.2 pounds of Palmer's *Myrmidon* to 2.502 pounds of Laird's *Sprightly*; but comparisons here are specially illusory, as Palmer's *Syren*, of the same design and equipment as the *Myrmidon*, burned 2.49 pounds. In former vessels 2.2 pounds and 2.3 pounds were frequently attained, but on an average this year's results may be considered very satisfactory. In the 30-knot boats there is a range in power between 6,141 and 6,961; but 6,400 seems a fair average, which means nearly 20 I.H.P. per ton of displacement. The *Charger* and *Hasty* belong to the original order of 26 and 27-knot boats; these two were built by Yarrow, and re-boilered by Earle's Company. They are between five and six years old. They were of 26 knots speed when new; the new boilers have not added anything on this score.

The four torpedo boats included in our list are interesting because of the fact that they mark an advance upon the 130-ton vessels hitherto built; their displacement of 180 tons enables the scantlings to be much heavier, so as to improve their sea-going qualities. The speed, too, is higher—twenty-five as compared with twenty-three knots; and in the last the remarkably low coal consumption of 2.009 pounds is recorded. This, if we mistake not, is the lowest rate of consumption recorded for torpedo craft for many years, if, indeed, it has ever been excelled. The Admiralty have since ordered four more vessels of the same type from Messrs. Thornycroft, and have, we understand, laid it down as a condition that, as far as possible, the parts of the machinery, &c., of all eight boats should be interchangeable. This is an important move, which must be commended and ought to be extended. Our warships, by reason of the necessity of getting the highest results per unit of weight and for other reasons, are specially liable to get out of gear, and it is of the greatest importance that their repair should be executed in the shortest possible time. Victory must rest with the navy which can get a

second fleet to sea after the first decisive engagement cripples, more or less, all the vessels engaged. It may, therefore, be most advantageous to refit one or two ships with available items from others. For ordinary overhaul, &c., the advantages are already appreciated in other branches of engineering. There are difficulties, but that is only another way of saying that the ordinary zest of the technical officers at the Admiralty will be quickened.

HIS IMPERIAL GERMAN MAJESTY'S CRUISER *VINETA*.

By Commander Richard Inch, U. S. Navy.

The German cruiser *Vineta* arrived at the yard of the Newport News Shipbuilding and Drydock Company on Friday, November 28, 1901, and was in dock for ten days from November 29th. She left the yard at 9·30 A. M., December 17, 1901.

The *Vineta* was built at Dantzig, Germany, in 1897, and is a protected cruiser of 5,900 tons displacement, 345 feet 7 inches long, 57 feet 10 inches beam, and a mean draught of 21 feet 8 inches. Her machinery was designed to develop 10,000 horse-power. Her greatest speed is 19 knots, and the normal coal supply is 500 tons.

Her battery consists of two 8.2-inch Q.F. guns, in turrets, one forward and one aft; eight 6-inch Q.F. guns on broadside, in turrets; ten 3.4-inch Q.F. guns, ten 1.4-inch Q.F. guns, four machine guns, and three submerged torpedo tubes, one in the stem and one on either bow.

MAIN ENGINES.

There are three similar sets of main engines of the vertical, inverted, direct-acting, four-cylinder, triple-expansion type; each located in a separate watertight compartment. Steam of 13 atmospheres pressure is supplied by twelve Dürr boilers, located in six watertight compartments forward of the engines.

These compartments are small and the machinery is crowded, especially in the wing-engine rooms.

The *Vineta's* engines represent the general type adopted for use in the German Navy, and were selected from a number of competitive designs, a prize of 80,000 marks having been offered for the most suitable type submitted.

The wing engines are abreast each other and the middle one aft of them; the shafts are all in the same horizontal plane.

The cylinders, unlike those for engines of the same size in our service, have no steam jackets; they are supported by steel columns well stayed; the method of supporting cylinders and securing crosshead guides is similar to that adopted for engines in our service except that they do not appear so rigid, the tie rods and braces being secured to columns by bolts through forked ends of rods and lugs in columns.

The arrangement of cylinders from forward is as follows: H.P., M.P., 1st L.P., 2d L.P., the H.P. being forward. The H.P. and M.P. cranks are at angles of 180 degrees with each other, the two L.P. cranks are at 180 degrees with each other and at 90 degrees with the H.P. and M.P., with the following crank sequence, H.P., after L.P., M.P., forward L.P.

This arrangement is said to reduce the vibrations to a minimum and to equal any system yet tried, the vibrations being slight under all conditions of steaming.

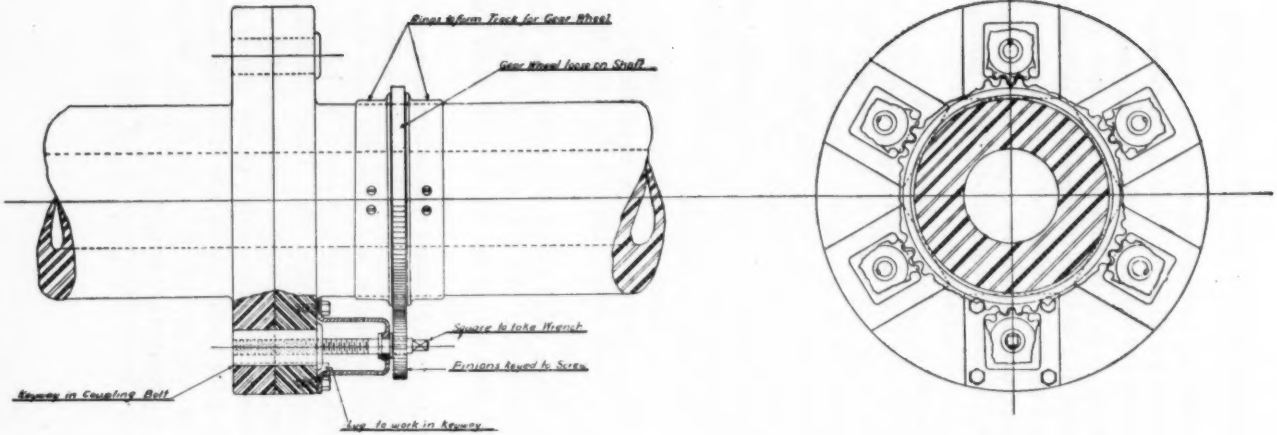
The Schlick-Tweedy system has not been used on this ship, but the results obtained here are said to equal those obtained by that system in a similar vessel, the *Hertha*, while the engines handle much more readily.

There is one piston valve for each cylinder, the H.P. being single ported and the M.P. and L.P. valves double ported; all valves are on the same side of the fore-and-aft center line of the cylinders.

The valve gear is of the Marshall type with continuous-motion steam reversing gear. A wheel about three feet in diameter acts as fly wheel for the steam gear and serves for hand reversing.

There are flange couplings just forward of the thrust bearings for uncoupling the engines not in use. These couplings are so arranged that, by means of suitable gearing, all bolts may be withdrawn or entered simultaneously; clamp brakes are fitted on the shafts aft of the thrust bearings to hold the shafts while coupling. The process requires from five to six minutes, during which time all engines are stopped.

There is a very liberal distribution of oil and water-service


Rings to form Track for Gear Wheel
Gear Wheel loose on Shaft
Square to take Wrench
Pinions keyed to Screw
Keyway in Coupling Bolt
Key to work in Keyway

German Cruiser "Vineta."
Gear for Handling Coupling Bolts.

pipes to all parts of the engine. A telescopic oiler connected to the crosshead supplies oil to the crosshead and crank-pin journals.

The propellers are all of the same size: diameter, 12.79 feet, with pitch variable from 13.45 feet to 17.71 feet; the starboard and middle are right and the port left-handed screws.

When steaming at full speed all engines make the same number of revolutions—about 135, develop a total horsepower of about 10,000, and give a speed of 19 knots. With the center engine alone the ship can steam 14 knots.

The ordinary cruising speed is 12 knots, and the revolutions for this speed are, when using one, two or three engines, 106, 91 and 80, respectively. Either seven or eight boilers are used. The coal consumption at this speed is 64 tons per day, and the amount of make-up feed water between 7 and 8 tons.

It is stated that the coal consumption for ordinary cruising is about the same whether using the wing engines or the middle engine alone. The ordinary practice is to use all three engines when going in or out of ports, then for about half the trip use wing engines with the middle uncoupled, and for the other half use the middle one with the wings uncoupled.

When the wing screws are in use and the center one uncoupled, the latter makes about one-half the number of revolutions of the others, while with the middle in use and the wings uncoupled, the wing screws make slightly less than half as many as the middle.

The three-screw system seems to be looked on with much favor, not a single unfavorable criticism being heard from any one on board the *Vineta*, but, on the contrary, all who expressed any opinion at all, whether Line or Engineers, spoke of it in the highest terms, and favored a continuation of its use.

At the working platform of each engine is secured a brass plate, upon which is stamped a table showing, for each knot of speed, the number of revolutions to be made by the engines when one, two or three engines are in use, and also the number of boilers necessary to furnish the steam.

AUXILIARY MACHINERY.

There are separate air and circulating pumps for each main engine; the air pumps are connected to the main engines and are worked by beams from the after L.P. crosshead.

Other pumps are of a type which appears to be similar in general principle to the Dow pump as used on some vessels in our service.

The feed pumps are located in the fire rooms, there being one main and one auxiliary pump in each compartment for each pair of boilers. These pumps are fitted with a combination gauge having two pointers, one indicating the pressure in the boiler and the other in the feed pipe.

Hydraulic power is used for operating the 8.2-inch gun turrets and their ammunition hoists, the hydraulic pump for this purpose being located in the middle engine room.

A dynamo driven by a compound engine and supplying current at 110 volts is located in the middle engine room. This machine is intended primarily for operating the 6-inch gun turrets and ammunition hoists; there are three other dynamos in the forward part of the vessel which are ordinarily used for lighting purposes, but all the dynamos may be used for any or all of these purposes.

The wiring throughout the ship is secured to the bulkheads, the wires being well insulated but not enclosed in moldings or otherwise protected.

There are three evaporators and distillers; two for the make-up feed with a capacity of 76 tons per day, and one for drinking water.

They are of the type furnished by Paape & Henneberg, Commandit Gesellschaft, Hamburg, and are said to be very efficient, and light in weight.

There are six steam blowers to furnish forced draft, one in each boiler compartment, giving an air pressure of 2½ inches of water.

BOILERS.

The Dürr boilers of the ship were manufactured by the Dusseldorf-Ratinger Rohrenkessel-Fabrik, formerly Dürr & Com-

pany, of Dusseldorf, and with works at Ratinger, Prussia. They are arranged in six watertight compartments, two boilers in each compartment. The compartments have no doors from one to the other but each is reached through a very narrow, tortuous passage from the berth deck. In any compartment the two boilers are placed back to back and about two feet apart. The boilers on each side are placed against the central fore-and-aft bulkhead. The fire rooms are seven and one-half feet wide between boiler fronts and athwartship bulkheads, and have sufficient height to give ample room on the tops of the boilers for work. An outboard passageway about four feet wide connects the athwartship fire rooms. In the lower part of this passageway are placed the main and auxiliary feed pumps, twelve in all. Above, in this passageway is placed the forced-draft blower that delivers the air into a conduit that runs down between the boilers. The blower engine is a small, two-cylinder, compound, direct-acting engine.

There are two furnaces to each boiler, with twenty-five square feet of grate surface in each. There are two furnace doors to each grate. These doors open inwardly and have small toothed wheels on the ends of the hinge pins and pawls on the furnace fronts, so arranged that the furnace doors are held to any degree of opening. The grate bars are wrought-iron, in two lengths. The grates are entirely surrounded by fire brick, and the partition between the two grates of each boiler, rises to about one foot from the bottom of the lowest row of tubes.

The dimensions are in all respects the same as stated in the article in the JOURNAL for November, 1901, by Von Buchholtz, page 881, and in the notes on Naval Progress, July, 1901, page 305. All parts of the boiler are of steel, except the brickwork in the furnaces, the asbestos covering and the zincs. The tubes are seamless drawn, and are $\frac{3}{16}$ inch thick. They are closed at the back ends by taper wrought-steel plugs introduced at the front ends before the tube is put in place into the boiler. A washer and nut are then fitted by which the taper plug is drawn into position. It is found that the joint can be made tighter by loosely fitting this plug in place, putting a pressure of eighty

pounds on the tube and tapping the tube with a light hammer till the plug finds its own seating, then increasing the pressure, fit on the washer and nut and set up. The tubes are made with a taper at the front ends, which fit into the front tube sheet and they are tapped with a hammer till well seated. The small inside circulation tubes are made in two lengths, which slip over each other for a distance of three or four inches, and a split pin diametrically through both parts secures them. They are thus made to permit their withdrawal. They are screwed into and expanded in the flange which secures them in the diaphragm plate, and are supported at the back ends in the large tubes by three steel wires about three inches long, riveted to them, equally spaced and extending off like small wagon springs. These springs hold them centrally in the large tubes.

There are about fifteen zincs used in each boiler, of dimensions 8 by 4 by ½ inch, and suspended in perforated boxes.

The automatic feed regulator is a float in the drum which works through a system of levers and a rock-shaft, a cock in the feed pipe. The arrangement used seems to give satisfaction and the water is kept as steady as in a Scotch boiler and does not move up and down.

It is not necessary to maintain a certain water level with any exactness, and instances have been known where the water has disappeared in the glass gauges for several minutes without any injurious results. Two glass water gauges are used for each boiler, one outboard and one inboard, but no mica gauges are used. The pipes from the gauges are extended to the top of the steam drum and to near the bottom of the water box.

These boilers have been in use for over two and one-half years, and the officers and men of the *Vineta* speak in the highest terms of them. Not one tube has given out nor any serious leaks of any nature during that time. The boilers are not treated as carefully as Scotch boilers, as the furnace doors are freely opened at any time, even with forced draft, and no evil results from the inrush of cold air. Indeed, the tubes are cleaned by opening the doors while an air pressure of two or three inches is being maintained in the fire rooms. The dampers or baffle plates are shaken

back and forth and all the loose soot is blown up through the stack. A leaky tube may be withdrawn and a new tube inserted by one fireman in one hour. Steam is raised, after the water is at steaming level and the furnace primed, in forty minutes. The fires are extinguished by the use of the ash hose, and no special form of extinguisher is used.

The only spare parts for the boilers are twenty-five extra tube sets for each boiler and an equal number of plugs and plates for the tube holes in the front sheet. The boilers give no trouble from foaming when fresh water is used, but when salt water or soda is used the foaming is apt to be great.

After a boiler has been used for about 600 hours the small inner tubes are removed, put in a fire, and all the foreign matter burned off, this latter having the additional effect of annealing them; and the large tubes are cleaned inside with wire brushes. The time required to clean all tubes thoroughly for one boiler is six days. The fires are hauled after steaming and the boilers may be cooled down as rapidly as possible without any apparently injurious effects. The tubes have never been known to be stopped from scale, which is accounted for from the rapid circulation. Every opportunity was given for examination of the boilers, and one was opened and some tubes removed. The interior appeared very clean without any signs of salt. The manhole was 12 inches by 15 inches in the end of the steam drum, the heads of the drums being riveted to the shells.

Two boilers were under steam for auxiliary purposes, and it was noticed that the water carried about half way up in the glass and was very steady. The fires burned well with a good draft. The ash pans had a couple of inches of water in them. The front doors over one furnace were opened, and the nut and dog plate were removed from over one tube hole to show the freedom from leakage. There was no sign of water. Then the back doors were opened, and the nut and washer were removed from the end of one tube and there was no sign of a leak.

The coal used in port for ordinary purposes with one boiler in operation is about seven tons per day.

The drum and front box are drained of water by the drain

cocks at the bottom of the box; the inclined tubes are not drained ordinarily, and when it becomes necessary to do this a syphon is used. This is a copper pipe about $\frac{3}{8}$ of an inch outside diameter and about 9 feet long, bent at right angles about 1 foot from one end. This operation requires about two hours.

The boilers have given no trouble since being installed in 1897, have had no leaky tubes, nor have any tubes been replaced since they have been in service. From a limited inspection of two boilers, one opened and one with a steam pressure and in use for auxiliary purposes, and from all that could be learned, they seem to be in excellent condition and to have given great satisfaction. All on board are loud in their praises and say the boilers have worked perfectly and have caused no worry.

INTERIOR COMMUNICATION.

To pass from one engine or fire room to another, it is necessary to go up on the protective deck, as there is no communicating doors. This is rather inconvenient, but it decreases the floor space required for the machinery by omitting the fore-and-aft passages.

The means of communicating with various parts of the ship appear to be very good and are essentially as follows:

Telephones are extensively used, the instruments being heavy and apparently very substantially built, with two receivers; it is stated that a message from the bridge may be heard in the engine room twelve or fifteen feet from the receiver when the engine is running.

Voice tubes are not extensively used, but those fitted are large and have easy bends.

The engine-room telegraphs are electric, and are said to be entirely satisfactory. No mechanical telegraphs are installed

There are two systems of electric telegraphs from the engine to fire rooms; one of these is an arrangement by means of which the engineer can signal to each fire room the amount of coal to be used, and after setting the instrument, it will automatically ring a bell in the fire room at the desired intervals when coal is to be gotten out and furnaces to be fired. On half the furnaces, doors

are opened at the same time for firing. At the first signal from the engine room furnace doors Nos. 1 and 3 of each boiler (one in each fire box), are fired, coal is then gotten out and at the next signal Nos. 2 and 4 are fired.

The other fire-room telegraph indicates condition and speed of engines, also whether more or less steam will be wanted.

There is also an electric helm indicator in each engine room.

Each engine room is fitted with vacuum revolution indicators to show the number of revolutions being made by the other engines.

This indicator is the type manufactured by Schootfeld, of Kiel, and it is said to be very accurate. It is used on a large number of German vessels, both naval and merchant.

PERSONNEL.

The total complement of the ship is 440 men and about 25 officers.

The engineers' division consists of one chief engineer, called staff engineer, three assistants, called marine engineers, thirteen machinists, and 157 men.

The force is divided into three watches of four hours each, with an officer in general charge, a machinist in each engine room and one in charge of all fire rooms, one fireman for each boiler, one oiler in each wing-engine room, and two in the middle room.

A full watch consists of 36 men.

The engineers' division has complete control of everything of a mechanical nature on board ship, including electric plant and gun mechanism, as well as hull and steel fittings.

All the men are trained as mechanics, and it was stated that any fire-room man was competent to renew a boiler tube or to do small jobs about the engines and boilers.

They apparently have no rating corresponding to that of coal passer in our service.

A MACHINIST APPRENTICE SYSTEM FOR THE NAVY.

By Lieut. T. W. Kinkaid, U. S. N.

In the Naval service technical difficulties are not the only ones that confront the chief engineers of our ships. No matter how high his professional and executive ability, the officer is hopelessly handicapped if he have not the proper men to do his bidding. Firemen, oilers and water tenders can be trained from raw material in a reasonably short period; but machinists, of whom our larger ships require as many as twelve or more, are not to be had in sufficient number. A fine ship without a proper complement must be considered a "lame duck."

It is not surprising that young men with good shop training are not desirous of going to sea as enlisted men. The inducements in the matter of pay are not great, as the first compensation is only forty dollars per month. Even after a considerable lapse of time, the machinist, second class, cannot be rated for higher pay unless a vacancy should occur on the ship to which he is attached. Finally, when, partly by virtue of merit and partly by lucky chance, he steps into a vacancy in the chief machinist rating, his pay is only seventy dollars per month, which is little enough for a skilled man who gives up home comforts and associations, and has to perform much of his duty at night and on seven days of the week.

The establishment of the rank of warrant machinist has done something toward inducing good machinists to enter and remain in the service; but the number of such prizes is limited, and the efficacy of warrant rank as a drawing card is limited correspondingly.

I have always thought that one of the most potent causes of discontent among the enlisted men, especially the intelligent men

in the higher ratings, has been the utter lack in naval regulations of any provision for their shore duty. Going to sea, with occasional liberty in domestic and foreign ports, may constitute a satisfactory career in the eyes of the younger men of the service, but there comes a time in the life of every man before the mast when continuous sea duty becomes monotonous. At this juncture many good men fail to re-enlist, and, having once obtained a footing on shore, they remain permanently out of the Navy. Matrimony plays a prominent part in taking men from the service. It is natural, of course, that men should wish to marry, but without shore duty married life is practically impossible.

The question "What shore duty would you give these men?" is easily answered. Most of the machinists on shore duty could be profitably employed at our navy yards, in the shops and on ships under repairs; others would be extremely useful as assistants to inspecting officers at shipyards, steel works, ordnance factories, and so forth. Those employed at navy yards should have quarters in barracks; those on detached duty should receive commutation for quarters and rations.

Even if the allurement of shore duty were offered, I believe that there would still be a dearth of machinists; and I am satisfied that the most practical method of supplying the deficiency would be through the agency of a properly organized and administered apprentice system. I believe that we should take in our men as we do our officers—while they are young. It is a wellknown fact that under the old apprentice system trades were but slowly learned, because frequently the master had a selfish interest in retarding the advancement of his pupil. But it is safe to say, I think, that a system could be organized within the naval service that would give us well qualified and well disciplined young mechanics, fit for any machinist duty, afloat or ashore, at the end of three years of training.

Assuming such a system in existence, and the period of enlistment on probation as four years, the age limits at enlistment we may take at seventeen and nineteen years. The machinist apprentice should spend his first year at a navy yard, on the Atlantic

or Pacific coast. The apprentices should be quartered in barracks. They should be divided into sections of about twenty boys each. The instruction at each yard selected for apprentice training should be under the supervision of a commissioned officer, assisted by two warrant machinists especially selected for the duty. A scheme of instruction and discipline, prepared under the supervision of the Bureau of Steam Engineering, should be incorporated in the navy regulations. An approved glossary of technical terms as used in the Navy should be prepared for the instruction of the boys. The rating for the first year of service would be machinist apprentice third class, and the pay might be put at sixteen dollars per month.

In order to give the young apprentices healthful recreation within the limits of the navy yards the barracks in each instance should adjoin a gymnasium equipped with the usual apparatus, and including baths, swimming tank and bowling alley. There should also be provided a reading room supplied with trade papers and other reading matter. The expense of the reading room equipment should be borne by the apprentices.

Should the machinist apprentice be retained in the service for a second year of instruction he should be given the next higher rating and the pay of thirty dollars per month. The second year should be spent at sea in the performance of the duties of oiler and machinist's helper. Machinist apprentices at sea should be in excess of complement.

The third and final year of instruction should be at a navy yard, with the rate of machinist apprentice first class, and pay of forty dollars per month. The rate of machinist second class should be abolished, and machinist apprentices first class should, after a year in their rating, be eligible for promotion to the rate of machinist, with pay of seventy dollars per month. Chief machinists should receive eighty dollars per month.

Quarterly reports as to aptitude, industry and general conduct should be made to the Department, and apprentices falling below the standard should be summarily dropped.

I have not outlined a course of instruction for the apprentices at navy yards. There are many officers in the service who are

well qualified to devise a course in the machine shop, foundry, pattern shop, and so forth, and such a programme would doubtless be forthcoming at short notice if required. Some instruction in the coppersmith's art would increase the all-around usefulness of the young machinist.

Finally, I think it is axiomatic that the more good men we get and retain in the service the more attractive will it become to the good men outside.

SOME NOTES ON MARINE SHAFTING FORGINGS.

By Lieutenant Commander George S. Willits, U. S. N.

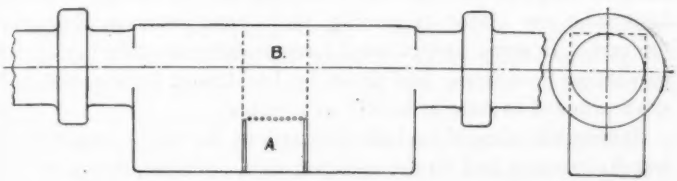
1. The tubular shafting now in use is forged solid, as a rule, and then bored axially to the required dimension. When sections of tunnel and tail shafts are long the difficulty of making inspection for surface defects in the bore is evident. A large, portable, incandescent lamp, secured horizontally in a semi-cylindrical reflector on the end of a long rod or pipe and run into the axial hole immediately after the last cut has been made, and while the metal is bright and clean, provides a good means for making the desired inspection. A mirror set near the end of the rod, at an angle of 45 degrees, and so arranged as to keep any rays of light direct from the bulb out of the observer's eyes, the use of a pair of high-power binoculars, and a slow, careful and *spiral* examination, make the observer reasonably sure that no defects will escape detection.

2. In boring axial holes in shafting of nickel-steel or high-carbon steel, it is necessary to renew the cutters about every two or three feet of progress. The vibrations of the boring bar and the character of the borings will indicate to a skilled and experienced mechanic the time for withdrawing the bar and fitting new cutters. By careful grinding and fitting of these cutters it is not difficult to keep the bore uniform in diameter throughout. Two cuts are generally taken, and each carried clear through from one end, though some lathes are rigged to work at both ends simultaneously, and boring is sometimes so done. In the latter case there is always danger of a shoulder being formed at junction of cuts.

3. In the oil-tempering process a section of shafting is suspended by one end in a vertical furnace, one side of which is hinged for the whole height of the furnace, a bright red heat is

given the shaft by the use of oil burners set at intervals around and up the furnace; the movable side of the furnace is then swung open and the shaft carried out by an overhead crane until over the oil pit, when it is rapidly lowered until submerged. Cotton-seed oil is used in the pit, and it is circulated from top to bottom by an oil pump, and kept cool by water circulating in the jacket formed around the walls or lining of the pit. When cold the shaft is lifted out and then carefully annealed. Again when cold it is ready for final machining.

4. Twisting a solid-forged, two-throw section of crank shaft is an interesting process. The rough forging is similar in shape to the accompanying sketch:



The block *a* is slotted and drilled out, the portion *b* remaining is turned cylindrical on the main axis, the middle of the forging is heated and the twisting done under the press by means of a heavy *wrench* made especially for the purpose. It is not practicable to obtain test specimens from the twisted part of such a forging, but tests made on similar material similarly treated have given results superior to those obtained from portions of same pieces not affected by the twisting.

ORGANIZATION OF THE ENGINEER DIVISION ON BOARD A MAN OF WAR.

By Lieutenant C. W. Dyson, U. S. N.

Discussion Continued.

Lieut. Commander W. N. Little, U. S. N.—Lieutentant Dyson's paper is timely, and should be regarded as a valuable addition to the literature of our profession by our brethren of the Line who are about beginning their experience as Engineer Officers. In some particulars I have preferences differing in organization from those laid down by Lieutenant Dyson, which I shall proceed to state as briefly as possible.

Station bill should include the stations for every evolution—watch, cleaning and repair, abandon ship, collision, fire quarters, general quarters, steaming station for all boilers and for full power.

To avoid extreme size, the bill should for larger ships be divided into three parts—one part to each section.

It is a great convenience to be able to read off the station against a man's name without (encyclopædia fashion) being referred to some other sheet located in some near or remote part of the department. Simplicity in the arrangement is appreciated by men in the fire-room class, and saves the time of officers interpreting for them. I have tried both arrangements thoroughly and would not use a divided watch bill, that is one with a key to it, under any conditions. Its only merit is convenience in its making.

The three-section arrangement in my opinion is better than the four-section, as in case of using all boilers all men would be on duty with their sections in three watches, and when not needed could be formed into a supernumerary squad for all day work, or for work with their watches whenever night and day repairs are required. In cases of long-distance steaming, particularly in hot

weather, it is desirable to have a few supernumerary men in the department at work and available for any emergency at all times, as otherwise the emergency may make it necessary for men who have worked all day turn out during the night following to fill vacancies, which is something of a hardship.

In case of change to full-power steaming, the four-section arrangement has a decided advantage, but the occasion is so extraordinary as to be negligible in view of the advantages above cited. Moreover it is rarely that the engineer divisions of our ships can afford four efficient steaming sections.

Laying out Work in the Departments.—Under this caption as carried on at present, Mr. Dyson states that "when the working hours are over, the old detail list is destroyed and a new one is made out." This has not been my practice. I have always made it a habit to file the working lists. Each working list should be arranged so as to show the ship number, watch section, and permanent detail.

On the reverse of the working or watch list is the list of work to be done. This list should be made out or revised every evening (or a fresh working list made out) for the following day and the old one turned in for filing. All new job orders should be inscribed in the work list with a serial number as soon as the order for it is received from the senior engineer. When the job is begun, a check mark is made against the job number, thus, ✓, and when completed a reverse check mark is added, thus, ↘, making a species of cross, thus, ✓↘. By reference to the work list at any time the fact of a job being under way or completed can be determined without questioning. When a man is detailed for a job, the record is made by placing the job number to the right of the man's name on the work or watch list. When a man is taken off a job a circle is drawn about the job number against his name.

Instead of throwing away the work lists, they should be filed for reference. Watch and work lists should be printed or mimeographed; spare copies are useful on many accounts; application to the flag secretary will secure the necessary services of the printer.

The coppersmith, blacksmith and boilermaker, when ship is under way, should, if they are not needed for mechanical work, be put on watch supervising the coal tally and coal passing. It is of the utmost importance to secure an accurate tally, and an accurate tally can be assured by careful observation, inspection, and, in case of offenders, prompt action at the mast. It is a great mistake to overlook offenses of this kind and then throw up one's hands in despair of securing a fair tally.

An excellent scheme of organization may be nullified by carelessness in execution. Much time is wasted by mechanics of the force failing to report completion or progress of work. To obviate this, all should be required to report progress at knocking-off time, morning and evening. This makes it easier for the officer of the watch and keeps him properly informed. It is less trouble for each leading man to report to the officer of the watch than for the latter to make as many trips for information as there are jobs under way.

A working list can be kept posted by the messenger of the watch, after very little instruction, to meet the changes made in detail during the day. Also, a synopsis of the work list can be made by him, accounting for the entire force. It is very useful to the senior engineer officer, and generally results in securing the services of several men who would otherwise be overlooked.

The synopsis is made by writing a brief of the jobs taken from the work list, in a vertical column at the left of a page. At the top of the page write the several ratings in the force. Place under the ratings and on line with the job, the number of men employed on that job; sum up the number of each rating employed on all jobs, and on the horizontal line the number of men (all ratings), employed on each job. Summing up the end and bottom lines affords an excellent check on the accuracy of the work list. I have used this style of work and watch list since 1885 with satisfactory results. It should be remembered that no organization can be made to compensate for a lukewarm administration. Systematic inspections, reports, punctuality and strict accountability in all matters of duty are absolutely necessary to

efficiency in any department, and not the least so in the department of steam engineering on shipboard.

A poor scheme well administered and faithfully executed is better than a good organization which fails through slipshod management.

The men stowing bunkers should, in my opinion, be placed under charge of water tenders, who should be held strictly responsible for the stowage and for closing of watertight doors in bunkers while coaling, and they should be obliged to keep a record of the watertight doors which they close and the time they were closed while coaling. A strict accountability for closing the watertight doors in bunkers while coaling can thus be secured.

Lieut. T. W. Kinkaid, U. S. N.—I agree with Lieutenant Dyson in his contention that the subject of which he has treated in this article is of the first importance. While it is desirable to secure a clocklike working of the department that will give the chief engineer time for thought and recreation, yet care must be taken that the system of organization chosen is one that will work fairly well even under adverse circumstances, as when men are sick or for other reason absent.

Mr. Dyson's assignment of warrant machinists and the enlisted men for repairs and cleaning agrees in the main with that dictated by the experience of many engineers since the construction of the new Navy began. The chief yeoman, while nominally in charge of the store rooms, will in practice see but little of them, as the system of red tape which prevails in our service will keep him busy with his pen most of the time. I would have three store-room keepers, who would perform no other duty than that of looking out for the stores and certain cleaning stations in the vicinity of the store rooms. These three men should in justice hold the ratings of yeoman, first class, second class and third class, respectively. They would stand watch at their posts at sea and in port. At general quarters two of them would act as oilers.

Basing the station bill upon the requirements of general quar-

ters is now standard practice. From the form of his model bill, I judge that Lieutenant Dyson has the same general-quarters station for a man whether he be on watch or off. While in general I endorse this plan, yet I believe it is better for the men assigned to the powder division to go there only when relief. The exceptions would be the cooks, who would be assigned permanently to the powder division for general quarters. The system, which is in practice on some ships, of having distinct sets of duties for the first and second reliefs is objectionable.

I cannot see any advantage in the plan of dividing the division into four sections. When steaming, the men standing watch in the cold boiler rooms can be advantageously employed either in their own compartments or elsewhere as occasion may demand. As the regulations require the boilers to be used equally, each fire-room crew will, in the long run, get its due share of steaming. When a full-power trial is to be run in two watches, in accordance with the regulations, there is no simpler plan than to assign the men to duty according to the two natural divisions made by their ship's numbers—odd or even. In the case of the chief petty officers designated by letter, it is necessary to have the distinguishing letter followed by some odd or even number, as L_1, M_2, etc.

The system of numbering the stations undoubtedly makes for compactness of the bill, but I should think it would be troublesome for most of the men to grasp. The cleaning bill may as well be kept separate, and it may with advantage contain the pay numbers. The principal items of the general-quarters bill should not be smothered by too many extraneous items. The more important stations should, of course, have two or more men assigned them, and these men should preferably be from different sections of the division.

I believe in having a regular repair squad, which should include a machinist or two, the coppersmith, blacksmith and both boilermakers. Ordinarily the squad would work only in the day time, but in an emergency they would be called upon for night work also. They would, if necessary, be assisted by the men standing watch in the cold boiler rooms. With steam on all

boilers, the repair squad could be drawn on to fill certain vacancies in the watch lists. From time to time the boilermakers, blacksmith and the coppersmith should be assigned water-tender watches to keep them in touch with such work. At general quarters some of the members of the repair squad would be assigned to stations.

Mr. Dyson's remarks on coal stowage are pertinent and ought to evoke a sympathetic response. If the time ever arrives when we shall be allowed to wet the coal as it comes on board, some of the horrors of coal stowing will be abated.

I also agree with the author in his remarks on coal stealing.

A printed form of work sheet, bound in book form, as suggested by Lieutenant Dyson, would doubtless find favor if issued to the service.

NOTES.

THE BOILERS FOR THE NEW BRITISH WARSHIPS.

Admiralty contractors throughout the country are at the present time engaged in preparing tenders for the construction of two battleships, five armored cruisers, and two third-class cruisers; and the situation is rendered the more interesting in view of the fact that the Admiralty have developed their policy in connection with the boiler question, and thus there is a probability that in these new ships there will be fitted several different types of steam generators, which have been tested by long sea-steaming in various gunboats of the *Sharpshooter* class, and in one or two sloops of war. While the Belleville boiler was being extensively applied, experiments were continued with the Babcock and Wilcox, Niclausse, and other types, and thus data have been accumulated which has now resulted, under the stimulus of the Water-tube Boiler Committee, in a greater variety of water-tube boilers for the new vessels. Indeed, the most important question in connection with the new ships has reference to the type of boiler in use. Thus, in connection with the first-class cruisers, of which five are to be built by contract and one in the dockyard, four alternative boiler systems are proposed, although the Yarrow boiler gets first place in the specification, and there is thus more than a suggestion of its securing first consideration.

Although a comparison of the economy, of the facility in working, and particularly of the cost of repairs of such several types applied to one class of ship, would be the most important, we must at present be satisfied with an examination of the particulars of design, accepting these as indicative of the steaming capabilities of the different boilers. The power to be developed, it may be said, is 22,000 indicated horsepower, and—as in all warships—weight had to be minimized as much as possible so as to secure adequate armored protection, satisfactory bunker

capacity, a powerful armament, and a large storage of ammunition, the weight given may be assumed as being the least possible for the power stated, with assurance of success. In the primary design, twenty-two boilers of the Yarrow type are specified, in second and alternative arrangement twenty-five of the Dürr type, in a third thirty-four of the Niclausse, and in a fourth twenty-five of the Babcock and Wilcox. The steam pressure at the engines in all cases is the same—250 pounds—but in the boilers of the two last-named types a greater margin is allowed, the boiler pressure being suggested at 270 pounds, while in the Yarrow and Dürr boilers it is 260 pounds; but the difference is immaterial, and obviously no reducing valve is anticipated.

The Yarrow boilers have the greatest heating surface per unit of power to be developed—3 square feet per indicated horsepower, as compared with about 2.6 square feet in the other cases, the Babcock boiler having slightly more than the Dürr and the Niclausse. The Yarrow boiler is expected to consume more coal per square foot of grate than the others; the variation in the power expected from the bar surface being considerable—12.2 indicated horsepower per square foot in the Niclause; 14.4 indicated horsepower in the Dürr; 12.5 indicated horsepower in the Babcock and Wilcox type; and 20 indicated horsepower with the Yarrow boiler. As regards weight, the Yarrow type comes out most advantageously, although the difference is not

COMPARISON OF BOILERS OF DIFFERENT TYPES FOR 22,000 INDICATED HORSEPOWER CRUISERS.

Type of Boiler.	Belleville.	Yarrow.	Dürr.	Niclausse.	Babcock and Wilcox.
Number	31	22	25	34	25
Boiler pressure, pounds	300	260	260	270	270
Heating surface, square feet	50,300	66,000	57,000	57,200	59,000
Grate area, square feet	1,610	1,100	1,525	1,800	1,750
H. S. per I.H.P., square feet	2.29	3.0	2.59	2.6	2.68
I.H.P. per square foot of area	13.65	20	14.4	12.2	12.5
Total weight of machinery, tons	1,750	1,832	1,852	1,892	1,857
I.H.P. per ton	12.57	12.0	11.87	11.62	11.87

so great as might have been anticipated, the total being 1,832 tons, whereas the Dürr boilers, with the same machinery, weigh 20 tons more, the Niclausse 60 tons more, and the Babcock and Wilcox 25 tons more; thus the power per ton of weight varies only between 12 and 11.62, as indicated in the Table of particulars given.

Several cruisers now being constructed are of practically the same type, and known as the County class. Belleville boilers are being fitted to most of them, and here the power is exactly the same, so that a comparison is not without interest. The heating surface allowed per I.H.P. is less than in any of the four alternative designs, being 2.29 square feet as compared with from 2.59 to 3 square feet, while the power per square foot of grate is 13.65 I.H.P., as compared with from 12.2 to 20 I.H.P. In the matter of weight the Belleville boiler has the advantage, the total, including machinery, being 82 tons less than the lowest of the four alternative designs, and 142 tons less than the highest. This is the more remarkable as the engines do not differ much.

It may be said that the machinery is to be of the triple-expansion type, with four cylinders, as now adopted in all naval practice, the high-pressure having a diameter of 37 inches, the intermediate of 60 inches, and the two low-pressures of 69 inches, the piston stroke being 42 inches, so that at 140 revolutions, the usual piston speed in Navy ships of 980 feet per minute will require to be made to get the power required. The ships are to have a speed of 23 knots, when the displacement is 10,200 tons; this is 400 tons more than in the former ships of the same class, the length being 10 feet more—*i. e.*, 450 feet; breadth, 67 feet, as compared with 66 feet; and the depth, 38 feet 4 inches, or 1 inch more, while the draught is maintained at 24 feet 6 inches. The side armor will be of 4 inches thickness, and the armament will include, as we described in a recent article, two 7.5-inch guns, with ten 6-inch weapons, as well as a large number of smaller guns.

In the case of three battleships to be built, the question of boilers is equally interesting, as in this case Babcock and Wilcox boilers are to be adopted in two, while in the third there is pro-

posed a combination of cylindrical with this same design of water-tube steam generator. Here, again, comparison is possible with the Belleville system, for the new battleship machinery will be very similar to the engines of the six vessels of the *Duncan* class now being completed, in which Belleville boilers are used to get the same power of 18,000 indicated horsepower from engines whose cylinders are of the same diameter as those in the new *King Edward VII* class. As to weight, the whole machinery with the Belleville boiler works out at 1,580 tons, while with the Babcock and Wilcox system the total becomes 1,735 tons, and with cylindrical boilers providing two-fifths of the power the total is 1,885 tons, or 300 tons more. It is scarcely necessary to labor the point that this extra weight involves forfeiture of some of the offensive or defensive qualities of the ship, or an increase in the weight and size of the ship to provide for the heavier boilers, and again for the extra material resulting for large dimensions of hull. Here are the leading particulars of the three systems:

COMPARISON OF BOILERS FOR 18,000 INDICATED HORSEPOWER BATTLESHIP.

Type.	Belleville.	Babcock and Wilcox.	Three-fifths Babcock and Wilcox, two-fifths cylindrical.
Number	24	16	14 and 6
Steam pressure, pounds	300	270	210
Heat surface, square feet	43,260	47,250	27,380 and —
Grate area, square feet	1,375	1,400	817 and 486
H.S. per I.H.P., square feet	2.4	2.63	.....
I.H.P. per grate area	13.1	10.4	.....
Weight of machinery, tons	1,580	1,735	1,885
I.H.P. per ton of machinery	11.4	10.37	9.54

It will thus be seen that the I.H.P. per ton of machinery is, with the combination 9.54 I.H.P., and with the Babcock and Wilcox 10.37 I.H.P., as compared with 11.4 I.H.P. in the case of the Belleville boilers. With the inclusion of the tank boiler in the steam-generation system a reduction of pressure has been made imperative—from 300 pounds and 270 pounds respectively with the purely water-tube-boiler arrangements to 210 pounds—and

this, again, has rendered larger cylinders, &c., necessary. Thus, in the *Duncan* class and, again, in the two ships of the *King Edward VII* class to have Babcock and Wilcox boilers, the diameters are to be the same—33½ inches in the case of the high pressure, 54½ inches in the intermediate, and 63 inches in the two low-pressure, while in the vessel with the double system of boilers the diameters are 38 inches, 60 inches and 67 inches respectively, the stroke continuing the same—48 inches—and also the piston speed—960 feet for 120 revolutions. The reduction in steam pressure, may, however, lessen the loss in auxiliary machinery when working simple or even compound, but a large part of this loss in economy has already been compensated for in high-pressure steaming ships by the use of the exhaust from these in distillers, &c., or by passing it into the intermediate or low-pressure cylinder receiver. However, we have no intention of speculating as to the probable results of the changes; the particulars of design are alone interesting enough for the present. It may be added, however, that the new battleships are to be 425 feet long, 78 feet beam, and 43 feet in depth, and at 26 feet 9 inches draught they will displace 16,350 tons. Their speed is to be 18½ knots.

The Admiralty have received tenders for the construction of two third-class cruisers which are improved vessels of the "P" class, of which about a dozen were built two or three years ago. These new vessels are larger, and of greater sea-going capabilities than their predecessors. They are to be 360 feet long between perpendiculars, 40 feet beam, and 21 feet 9 inches draught. With a draught of 14 feet 6 inches they will displace 3,000 tons. To get a speed of 21¾ knots they are to have machinery of 9,800 I.H.P. The engines using steam at an initial pressure of 250 pounds (reduced from the boiler pressure of 300 pounds,) will have cylinders of the following diameters: High-pressure, 24¼ inches; intermediate, 38½ inches; and two low-pressures of 42¼ inches. The stroke is to be 24 inches. The ten boilers are to be of the "Express" type, and the power to be got per ton of machinery is 17.88 I.H.P. per ton, which compares with about 20 I.H.P. in the case of the earlier vessels of the same class, so that it will be recognized that here, as in other respects, the Admiralty,

while aiming at maximum results, are, at the same time, doing everything that is possible to make these attainable under all conditions.—London "Engineering."

BOILERS FOR THE BRITISH NAVY.

Mr. Allen, the member of Parliament for Gateshead, has put some questions to the Secretary of the Admiralty which express the curiosity of a good many people, ourselves included. He asked when the Boiler Committee's report on the *Minerva* and *Hyacinth* trials would be published, and what arrangement, type or design of boiler was to be fitted into the new battleships and cruisers. Mr. Arnold Foster's reply was not very full, but while it leaves some matters in uncertainty, it is fairly definite on others. We learn from it that it is proposed to publish a further report on the trials of H. M. S. *Minerva* and *Hyacinth* at an early date. Two of the new battleships will be fitted with the Babcock & Wilcox boiler, and one of the battleships will be fitted with the combination of two-fifths cylindrical and three-fifths Babcock & Wilcox boilers. The type of boilers to be fitted in the cruisers has not yet been determined. The Babcock & Wilcox boiler is in favor in the United States Navy, and we learn with pleasure that it is to have a fair trial in our own warships. We trust, however, that the labors of the Committee, and the investigations by the Admiralty, will not be limited to one or two types, however full of promise. The Niclausse boiler is said to be doing well in the French Navy. It ought to be fully tested on an adequate scale in our own. A limited trial in a gunboat will satisfy no one.

We have said the Babcock & Wilcox boiler is being used in the United States Navy. It is an excellent representative of the large-tube type as distinguished from the Express or small-tube type, and we think it advisable to insist once more on the vital importance of keeping such tubes short in any boiler that is liable to be hard pressed on occasions. We have repeatedly stated that if the water tubes in a boiler are not more than about twenty-five diameters long it is almost impossible for them to boil dry, for

"steam plugs" to form in them, or for any accident to take place, so long, of course, as there is water enough in the boiler. This gives us, for example, a tube 8 feet 4 inches long and 4 inches in diameter, or 5 inches diameter and 10 feet 5 inches long. The former dimensions seem to be best adapted for use at sea. We cannot call to mind any instance in which tubes of these proportions, or shorter in relation to the diameter, have given trouble; far from it. We may point to the water tubes fitted by Mr. Drummond to the fire boxes of the express engines on the London & Southwestern railway, which have done as much as 60,000 miles, and appear to be just as good as when they were first made. These tubes are about 13 diameters long and very slightly inclined. We do not believe it is possible to put a water tube into a hotter place than the fire box of a locomotive.

If we compare such a performance as this with the results obtained by the long-tube boiler, the soundness of our contention becomes so apparent that we do not hesitate to say that by far the larger proportion of all the troubles encountered in the working of water-tube boilers is due to the tubes being too long. In the Belleville boiler this defect is carried to an outrageous excess, the tubes being as much as 200 diameters long, and even more, a defect aggravated by elbows and bends. Be it observed that we are not now referring to boilers of the Express type, in which the tubes are nearly vertical.

An instructive illustration of the importance of using short tubes for boilers hard fired is supplied by a report just published by the Board of Trade on the failure of tubes in a Babcock & Wilcox boiler at Weston Point, Cheshire. The boiler in question has 160 tubes, about 4 inches diameter, and no less than 18 feet long; that is to say, 54 diameters, or, say, twice the length we have named as the best. This boiler was made in 1898, and is of the best and most modern construction. It is fired by a Jukes automatic grate. The tubes appear to be of the best Swedish manufacture. Since July, 1900, the following tubes have had to be replaced: July 21st, 1900, one tube in bottom row; November 13, 1900, four tubes in bottom row; December 12, 1900, two tubes in bottom row; December 15, 1900, two tubes in bottom

row; July 15, 1901, two tubes in bottom row; July 18, 1901, one tube in bottom row; August 7, 1901, two tubes in bottom row; August 7, 1901, one tube in second row.

It will be seen that all these failures occurred, save one, in the bottom row next the fire. It does not appear that the tubes burst. They split, and leaked and were removed, all but the last one, the failure of which was made the subject of the inquiry of the Board of Trade under notice. No one was hurt. The boiler leaked, the fire was drawn, and it was found that a tube which had been replaced four days previously had bulged at a distance of about 4 feet from the front header, the bulge had two slits extending for about three-eighths of an inch in length by about one-sixteenth inch wide; the thickness of the material was reduced by wasting and stretching to one-thirty-secondth of an inch in both cases. The boiler had been working under normal conditions, burning about 18 tons of coal per twenty-four hours, upon chain grates with automatic stokers, the grate area being 56 square feet; the coal consumption was at the rate of about 30 pounds per square foot of grate per hour. A steam pressure of 190 pounds per square inch had been maintained, and the water level is said to have been at half glass. Upon examination the tube was found to be free from heavy scale, the bulged portion was cut out for better inspection, and it was noticed that the lower half of the tube, where the bulge had taken place, was covered with a coating of black oxide of iron, undoubtedly formed by steam having been in contact with the tube when it was red hot; the upper portion of the tube at this place and the rest of the tube, top and bottom, was coated with a thin white scale, the oxide of iron was about one-thirty-secondth of an inch thick.

Mr. G. M. Gray, reporting to the Board of Trade, holds that "the spilts in the tube have been caused by overheating of the material through shortness of water in the tube, this being brought about by over evaporation." And he then goes on to give his reasons for arriving at this conclusion. With his theory of the cause of circulation we do not on all points agree. He follows, however, in an important respect, a line of argument which we have ourselves pursued in a previous impression. His

contention is that if a tube is of considerable length, and presenting a fairly large heating surface to a very hot fire, more steam may be made in it than can readily escape, with the result that the water will "back" in it, and steam "pockets" will be formed in which there will be no water, and the pipe will be overheated. We may go a step further and say that the black oxide which forms being a bad conductor, the evil will be aggravated, and finally the tube will give way. The boiler, it will be seen, was rather hard fired, the rate of combustion being 30 pounds per square foot per hour. The lesson to be learned is, that a less rapid rate of combustion should be employed with these very long tubes. Assuming that the boiler produced 8 pounds of steam per pound of coal, the total evaporation was 13,440 pounds per hour. The effective heating surface was, we understand, 800 square feet. This gives an average evaporation of no less than 16.8 pounds per square foot of heating surface per hour. But the rate must have been four or five times as great in the bottom row of tubes, and is obviously too much for tubes 18 feet long. There is no reason why the Babcock & Wilcox boiler should not succeed perfectly with a rate of combustion double that named, but the tubes must not be more than twenty-four diameters long. The lesson we wish to enforce is that long tubes should not be used in his Majesty's ships.—"Engineer."

WATER-TUBE BOILERS FOR BRITISH VESSELS.

In the matter of water-tube boilers it is said that the Admiralty Committee, just named, is preparing a report on the series of tests between the *Hyacinth* and *Minerva*, and that it will be much more conclusive in its recommendations than was the interim report. The committee has, I am told, sufficient data to make proposals, and these will be more definite than anything yet expressed. Further tests determined upon for the two ships are more with regard to engine than boiler design, for it has been found that the *Hyacinth* does not give an increase of speed proportioned to her higher power. Trials are to be made to show the relative friction of the two sets of machinery at various speeds

of rotation, and for this purpose the propellers will be removed and brake gear applied. The tests of Babcock & Wilcox boilers are being continued in the sloop *Espiegle* as well as in the gun boat *Sheldrake*, and the results are said to be favorable. But the question of type for the new ships to be laid down is still unsettled. This is keeping back the armored cruisers of the County class, of which five are to be given out to contract, but the machinery of all of which will be built in private works. The use of a combination of cylindrical and water-tube boilers in each ship is probable, as was originally proposed in connection with the battleship *Queen*, now in progress of construction. The Germans favor this system, several of their vessels being fitted in such a manner that from 40 to 70 per cent. of the steam supply is from Schulz-Thornycroft boilers, and the remainder of the power from cylindrical boilers, though in later ships they have fitted water-tube boilers for all the power. The type of water-tube generator to be adopted in combination with the cylindrical boiler in the cruisers has yet to be decided, but alternative designs will be considered of small-tube and large-tube boilers along with the Scotch boiler.

It is probable that at least two of the three battleships about to be ordered will be fitted with Babcock & Wilcox boilers, as in the case of the *Queen*, but one at least will doubtless have a combination of Babcock & Wilcox with the cylindrical, as in the case of the United States cruiser *Chicago*. This combination will involve differences in steam pressure, but the cylindrical boilers will be useful for low-power steaming, which represents the pace for the larger part of the work of a warship, while the water-tube boilers will be available for securing rapid acceleration in pressure, power and speed in case of need. The lower pressure of the cylindrical boiler will serve also for the simple and compound auxiliary engines. The use of Express boilers in the cruisers should help to keep weights down, as they are lighter than the large-tube boilers. The Italian Navy has also appointed a special committee or board to make trials with various systems of boilers. The Belleville boiler is being fitted in the armored cruiser *Giuseppe Garibaldi* and the Niclausse boilers in the sister

ship *Varese*. These are vessels of 344 feet in length, 7,400 tons displacement, with engines of 14,000 I.H.P. to give a speed of 20 knots.—Glasgow correspondent of "Marine Review."

WATER-TUBE BOILERS.

A letter written to the "Times" by Messrs. Thronycroft and Co. raises the question of water-tube boilers in foreign navies. In spite of facts, a large section of the public have, we believe been led to conclude that the British Navy is at a disadvantage compared to foreign navies, by reason of having so large a part of the fleet fitted with water-tube boilers. In regard to the Thornycroft type, we are now informed by the Chiswick firm that out of 1,074,440 indicated horsepower placed in war vessels of fifteen countries, Great Britian owns no more than 294,350 indicated horsepower. Turning to the other well-known English firm that has become identified with water-tube boiler invention, we are not aware that a complete list has been published of the Yarrow boiler, but a table lately made public (which does not include some recent vessels) gives a total of 194,400 indicated horsepower placed in battleships and large cruisers of foreign navies. If we add to this the boilers in destroyers, torpedo boats, and the smaller cruisers, of which there are records of 157 additional boilers of this kind in foreign vessels, the total would be enormously increased. The above are two types of boiler of English design, and largely of British make; so that it might be supposed they would appear more largely in British vessels. In place of that we find that the number made for foreign vessels very largely exceeds that for home use. If we had details of the Normand boiler, the balance on the foreign side would doubtless be largely increased; whilst probably the Reed boiler would carry the figures somewhat in the opposite direction. These are small-tube boilers, which were originally not supposed to be suitable for big vessels, though, presumably, recent events have somewhat altered this opinion.

Turning to large-tube boilers, we find by a list of Belleville boilers fitted in British and foreign navies respectively, that our

own Government has purchased a total horsepower, roughly, about equal to that supplied to all foreign powers combined. Of the Niclausse boilers we have figures that are up to date. England has but 49,000 indicated horsepower in her Navy out of a total of 560,000 indicated horsepower supplied to all war vessels. With the Babcock & Wilcox boiler, again, the preponderance is immensely on the foreign side, this type of boiler having been fitted in British war vessels to the extent of 65,800 indicated horsepower; whilst in navies abroad there are boilers giving an aggregate of 166,150 indicated horsepower. It will be understood we speak here only of naval vessels, and it will also be remembered that the latter type of boiler especially has been used for a very large number of mercantile craft, as compared to the list of war vessels in which it has been placed. We do not quote the above figures as complete or comprehensive, but merely with a view of affording an idea of the extent to which the water-tube boiler has been fitted in foreign navies. If, as some persons appear to believe, and try to make the uninstructed public believe also, ships with water-tube boilers are to be incapable of carrying out warlike operations, it is not only the British Navy that will be rendered harmless in case of war.—"Engineering."

SMALL-TUBE BOILERS FOR LARGE VESSELS.

The growing confidence in the water-tube boiler of the small-tube type felt by foreign engineers and ship designers is well illustrated by the action of the Swedish naval authorities. Sweden has not a large navy, but it is administered with admirable efficiency. Two cruisers, of 800 tons each—the *Psilander* and the *Clas Uggla*—have lately been completed. They have machinery developing about 4,500 indicated horsepower, the steam being supplied by eight Yarrow boilers in each ship. An armored vessel—the *Dristigheten*—of 3,500 tons and 6,000 indicated horsepower, has also been lately completed. She also has eight Yarrow boilers. There are now in course of construction four other armored vessels of somewhat larger dimensions for the Swedish Navy. These are the *Aran*, *Wasa*, *Tapperhten*, and *Mantighten*. They are

each of 3,650 tons displacement, and have machinery which will develop 6,000 indicated horsepower. Each of these ships will likewise have eight Yarrow boilers. Turning to other foreign countries, we hear that it has been decided by the Austrian Government to fit the same boiler to three armored vessels about to be laid down. These are each of 11,000 tons displacement, and the machinery of each vessel will develop about 14,000 indicated horsepower. The Austrian naval authorities made a very practical trial of this boiler fitted in one of their vessels—the *Zenta*, which was sent on a cruise to the China seas. The results of this voyage are reported to have been so satisfactory that the further extension of the small-tube boiler for large vessels is looked on as an assured fact.

We have, on former occasions, made reference to the adoption of the Yarrow boiler into the Dutch navy. It is now about four or five years since each one of three large cruisers was fitted partly with Yarrow boilers and partly with cylindrical boilers. The results of the experiment were so satisfactory that the shell boiler was abandoned in subsequent vessels of the same type, and reliance was placed entirely in the small-tube boiler; in fact, it would appear that the Dutch Navy is to have nothing but Yarrow boilers in the ships now coming forward.

The boilers referred to are, doubtless, all of what is known as the "modified" small-tube type; that is to say, something is sacrificed of lightness, and, perhaps, to some extent, of economy in space, in order to secure greater durability and better fuel economy. The original Express boiler, of either the Thornycroft or Yarrow type, was admirably designed for the work it had to do—namely, to secure the maximum of speed in small craft, almost irrespective of other considerations. When long-voyage ships have to be dealt with, however, a different set of conditions arises. It is true that Professor Kennedy made some trials with the Thornycroft boiler in a torpedo boat some years ago, in the course of which a remarkable economy was obtained. That was with an Express boiler, and the figures were valuable; but it is a fact that on long voyages the water-tube boiler of the large-tube type has not proved so economical as the cylindrical boiler.

In order to bring the small-tube water-tube boiler to the same level in regard to durability as the older description of shell boiler, designers have been increasing the diameter of the tubes, bringing them from 1 inch or 1¼ inches up to about 2 inches, and at the same time thickening the gauge of the metal. This adds to durability at the expense of lightness.

Coal economy is obtained by adding to the heating surface, and also, in the case of the Yarrow boiler, by first passing the feed water through the outer rows of tubes—*i. e.*, those farthest from the fire—so that the coldest water is in contact with the coldest gases, according to approved boiler practice. Whenever this end can be attained, it is a pure gain. As a result of these changes it has been found that steam for 1,000 horsepower can be obtained from modified Yarrow boilers when occupying no more space than that which would be needed for cylindrical boilers giving only 930 horsepower; that is to say, space for space, the water-tube boiler gives 70 horsepower in excess of the horsepower supplied by the cylindrical boiler. In regard to weight, the saving due to the use of this water-tube boiler is 25 tons in every 1,000 horsepower. These, of course, are far less striking advantages—at any rate, in regard to weight—than those which have been secured when purely Express boilers have been substituted for return-tube boilers; still, they are substantial gains well worth securing. Messrs. Yarrow have now had extensive experience in the application of their boiler to large vessels, as well as torpedo craft, and we may conclude that by this time they have arrived at some definite conclusion as to what is the best compromise to make.

Turning to the leading small-tube boiler—that invented by Mr. Thornycroft, of Chiswick—we find it is also being placed in a large number of foreign vessels of large size. For instance, among others, in the United States there are two battleships of over 12,000 tons each, and having machinery in each of 16,000 indicated horsepower. In Germany the Thornycroft boiler has been taken up by Krupp, and, in consequence, has made considerable progress in that country. The design adopted is that known as "Schulz-Thornycroft"; in England it is the Thorny-

croft-Schulz." It resembles the *Daring* type of Thornycroft boiler. A certain number of tubes are, however, drowned tubes; that is to say, they open into the top drum or separator below the water level. The course of the gases is also different from that of the purely Thornycroft type. In addition to several German battleships and cruisers which have been fitted with the Thornycroft boiler, either wholly or in combination with cylindrical boilers, there are now in course of construction four coast-defence ships, each of 5,000 indicated horsepower, and two cruisers of 11,000 and 20,000 indicated horsepower respectively. These will have Thornycroft-Schulz boilers exclusively.

The German naval authorities have been feeling their way with commendable caution towards the adoption of the water-tube boiler of the small-tube type for large vessels. They fitted it first in conjunction with cylindrical boilers. In some of their earlier ships they used only 35 to 40 per cent. of Thornycroft boilers, but they increased the proportion of water-tube boilers gradually until nearly double the ratio was reached. That point having been attained with satisfactory results, the cylindrical boiler was thrown aside, as will be seen by the above statement, and complete reliance for steam generation is now placed in the Thornycroft boiler.

There are, of course, other descriptions of small-tube boiler to which reference might be made. These have been described from time to time in our columns, and doubtless reference might be made to the successes they have achieved. The two kinds we have named combine the leading characteristics of their type, and their performances are quite sufficient to establish the claim of the small-tube water-tube boiler to be used in large descriptions of naval vessels.

COMPARISON OF BATTLESHIP DESIGNS.

[From the "Engineer," London.]

Methods of classifying warships are legion. There is an official one common to most navies, whereby almost every ship is "first class" to satisfy or delude the tax-payer; there is the statis-

tical expert's system, whereby the class of any ship depends almost entirely upon the things to be proved; and, finally, there is the naval officer's system, based chiefly upon an unwritten instinct. This last is a rule-of-thumb system, invariably acknowledged to be "about right" by the impartial, but difficult to formulate further. Attempts to do so have been made by adding up energies of fires, but since energy implies armor penetration, and penetration as a factor of naval warfare is nearly dead by now, the "energy of fire" is not a reasonable method. By what means then, is the generally accepted naval computation arrived at? No one knows. Probably it is instinct alone that decides whether a ship is first or second class. Yet by taking results and working backward it is possible to find a mathematical formula which gives correct results.

Recently we published some particulars of a new method introduced into the naval war game, whereby units of fire are arrived at. Roughly, this is that two 6-inch = 1½ medium = 1 big gun. This, of course, is accepted all over the world as an approximate truth. Here, then, is one axiom to proceed on, and a means of reducing gun fire to a common denomination is placed in our hands.

There remain armor, speed, handiness and coal endurance. Of these, coal endurance is not a tactical feature, so may be discounted in assessing tactical values. Speed and handiness for equal dates are usually about equal. Tactically, they are of value rather for single ship actions than for fleet actions. It is practically as impossible to assess them as it is to assess personnel, and, like personnel, they may be omitted in seeking a common denomination of fighting value, so long as we recognize that the ship that is better armed and armored has, in 90 per cent. of cases, superiority in speed and handiness, and that these qualities in a high degree in an isolated ship are of no value to the fleet as a whole. This reduces us to armor only. Now, so far as naval officers are concerned, the vast majority hold that, in reason, all armor is equally efficacious, and is little likely to be penetrated. Without any straining of probabilities we may, therefore, put the "knockout" blow from penetration of a belt in

the same category as a machinery breakdown; that is to say, count it as a negligible factor in determining a general value. This leaves us with little to assess save the relative values of armored and unarmored guns. In part by working backward, in part by acting on instinct, we may, seeking only a general approximation, arrive at the following: 1 gun, armor protected = 3½ to 2 partially protected by armor = 4 unprotected.

Something of this sort is generally accepted by all who, discarding purely paper questions, reckon—without probably troubling to trace the mathematical steps of the problem—that where guns are unprotected, "crushing by superior fire" has been worked for, and internal arrangements to limit shell effect introduced largely; else the one-to-four proportion might not stand well. Great as the protection of armor is, casement backs are vulnerable, and a shell hitting a casement or battery is almost certain to damage muzzles, while an unarmored ship it might pass through and burst beyond. Yalu produced many instances of this.

Of displacement we have taken no count, the reason being that to possess a superiority of guns and armor, together with the increased speed, handiness, &c., for which all naval architects aim, increased displacement is an implied necessity, and chiefly a strategical quality.

Here, then, are some ships worked out upon this system, by which most ships fall naturally into classes. Where ships come upon the margin, determination must be left to such items as torpedo tubes, coal endurance, speed, age, displacement, &c., but otherwise this exceedingly simple rule will apply:

Reduce all guns of and over 4-inch, 12-pounders and the like being fitted for repelling torpedo boats, to the unit of fire denomination. Multiply every armor-protected gun by four; partially protected by from three and a half to two, according to the amount of armor, with a reduction if that armor is obviously barely proof against 6-inch shell, and count each unprotected quick-firing gun as a unit. The result will give, approximately, the relative fighting value of the ship as opposed to others.

As it is somewhat interesting, we have placed after our figures the classifications given by three of the naval annuals—Lord

Brassey's "Naval Annual," by "All the World's Fighting Ships," and by the "Naval Pocketbook"—to all recognized battleship types in the lists below. Obviously all these classification systems count in other things than mere fighting value. We have fixed seventy as the dividing line between first and second class, while second class ships must exceed forty. "Officially," all the battleships introduced are "first class"—save a few coast defence ships.

Now, of the relative values arrived at by this system, it may certainly be said that in most cases they tally closely with naval ideas. The naval man sees an immense gap between the *Majestic* and *Royal Sovereign* classes, with a big gap again between this latter and the *Admiral* class or the *Sanspareil*. The low figure of merit of the *Sanspareil* may come as a surprise, but no one carefully thinking out that ship's construction is likely to arrive at a widely different result. The high value of the *Cressy* and other armored cruisers is in accordance with French ideas, and, we may add, ideas fairly common over here too. Though pretty dicta about the inability of the armored cruisers to fight in the line are laid down in print, none can dispute that the only difference between them and battleships is in big guns, and a very slight inferiority in armor. Their one drawback is that the concentrated energy of the big gun may deal some vital blow, but against that we may well put their high speed, which, in a fleet of them, would be a counterbalancing factor. Mathematically, therefore, it would look as though those who characterize the French theory as foolishness were the foolish ones. As regards the French fleet, the figures here reached fit closely to the usual French view that the *Suffren* is fully equal to our *London*. The *Bouvet* works out better than the *Charlemagne*—a claim that has been made in France. Her gun positions cause a loss of broadside fire, but against that we may place the longer survival of four big gun positions against two.

German ships work out at an unexpectedly high figure of merit. It may be observed that Germans always contend for the superiority of their designs, claiming that the excess volume of fire more than counterbalances a slight loss of protection. The

Names of ships.	Figure of merit.	This system.	Classed.		
			"Naval Annual."	"Fighting Ships."	"Naval Pocket-book."
BRITISH.					
King Edward (8 x 4) + (8 x 4) + (10 x 4)	= 104	1	1	1	1
Majestic (8 x 4) + (8 x 4) + (4 x 3)	= 76	1	1	1	1
London (8 x 4) + (8 x 4) + (4 x 3)	= 76	1	1	1	1
Royal Sovereign (8 x 3) + (4 x 4) + (6)	= 46	2	1	2	1
Trafalgar (8 x 4) + (6 x 2½)	= 47	2	2	2	1
Centurion (8 x 4) + (2 x 4) + (3)	= 43	2	2	2	1
Anson (8 x 2) + (6)	= 22	3	2	3	1
Sanspareil (4 x 4) + (2) + (6 x 1½) + (6)	= 33	3	2	2	1
Cressy (4 x 3) + (12 x 4)	= 60	2	...	...	...
Thunderer (4 x 4)	= 16	4	3	4	2
FRENCH.					
Republique (8 x 3½) + (6 x 4) + (12 x 3½)	= 94	1	1	1	1
Suffren (8 x 3½) + (10 x 4) + (8)	= 76	1	1	1	1
Charlemagne (8 x 3½) + (8 x 3) + (2) + (8)	= 62	2	1	1	1
Bouvet (8 x 3) + (8 x 4) + (8)	= 64	2	1	2	1
Marceau (8 x 2) + (17)	= 33	3	2	3	1
Jemappes (4 x 4) + (1½)	= 17½	4	3	3	4
Jeanne d'Arc (3 x 3) + (8 x 3) + (6)	= 39	3	...	...	...
Leon Gambetta (6 x 3½) + (4 x 4) + (12 x 3½)	= 79	1	...	...	...
GERMAN.					
Wittelsbach (8 x 3½) + (12 x 4) + (6 x 3)	= 88	1	1	1	1
Kaiser Friedrich (8 x 3½) + (18 x 3)	= 82	1	1	1	1
Brandenburg (12 x 2½) + (3)	= 33	3	1	2	1
Ægir (6 x 3) + (3)	= 21	4	4	4	4
Furst Bismarck (8 x 3½) + (2 x 4) + (10 x 3)	= 66	2	c	2	c
RUSSIAN.					
Borodino (8 x 3½) + (12 x 3½)	= 70	1	1	1	1
K. T. Tavsitchesky (8 x 4) + (16 x 4)	= 98	1	1	1	1
Trisvititelia (8 x 4) + (8 x 4) + (2)	= 66	2	1	1	1
Poltava (8 x 3½) + (12 x 4)	= 70	2	1	2	1
Gromovoi (3 x 4) + (3 x 1½) + (12 x 3) + (4)	= 56½	2	...	...	...
Peresviet (8 x 3) + (8 x 4) + (2 x 3) + (1)	= 63	2	1	2	4
Apraksin (6 x 2½) + (4)	= 19	4	4	4	1
JAPANESE.					
Shikishima (8 x 4) + (8 x 4) + (6 x 3)	= 82	1	1	1	1
Asama (6 x 4) + (10 x 4) + (4)	= 68	2	...	...	...
ITALIAN.					
Brin (8 x 4) + (6 x 4) + (12 x 4)	= 104	1	1	1	1
V. Emanuele (4 x 4) + (12 x 4)	= 64	2	1	1	1
Sardegna (8 x 2) + (8) + (8)	= 32	3	1	3	1
UNITED STATES.					
New Jersey (8 x 4) + (12 x 4) + (12 x 4)	= 116	1	1	1	1
Maine (8 x 4) + (14 x 4) + (2 x 3)	= 94	1	1	1	1
Kentucky (8 x 4) + (6 x 3) + (7 x 4)	= 78	1	1	1	1
Indiana (8 x 3½) + (8 x 2) + (4)	= 48	2	1	2	1
California (6 x 3) + (14 x 4)	= 74	1	...	...	...

United States, which manages on paper, at all events, to get the maximum of both, is, of course, still more to the fore. By no paper calculations can American new designs be shown to be elsewhere.

Russian new design, as exemplified by the *Borodino* class, does not show up well. No advance upon the *Poltava* is indicated, and both types barely reach the first rank. The *Poltava*, by reason of the absence of submerged tubes, is relegated to the second rank. The two types, of course, are armed with the same number of guns. The Italian *Victor Emanuele* comes still lower. She, of all ships, is avowedly a compromise, and, of necessity, great sacrifices are made in her to secure strategical qualities that do not concern purely tactical values—ship against ship.

The system enunciated above is, of course, equally applicable to cruisers.

THE PARSONS STEAM TURBINE.

During the past season the *King Edward*, fitted with Parsons steam turbine engines, has been running on the Fairlie-Campbeltown route, as our readers are aware. The managing owner has had a careful record of the coal consumption kept. The following summary is from the figures that have been tabulated. The *Duchess of Hamilton* is a paddle-wheel steamer of the same dimensions as the *King Edward*, and is one of the crack boats of the Clyde estuary:

COMPARATIVE STATEMENT OF SPEED, MILEAGE AND COAL CONSUMPTION OF THE PADDLE STEAMER "DUCHESS OF HAMILTON" AND THE S. S. "KING EDWARD."

	Duchess of Hamilton.	*King Edward.*
Total coal	1,758 tons 13 cwt.	1,429 tons 16 cwt.
Miles run	15,604	12,116
per ton	8.87	8.47
Number of days running	111	79
Daily average consumption	15 tons 17 cwt.	18 tons 2 cwt.
Average speed	about 16½ knots.	about 18¼ knots.

The figures as to consumption are satisfactory, inasmuch as they refer to an extended period of running. Other things being

equal, one would naturally expect that the *King Edward*, being considerably the faster ship, would burn much more coal per mile. That the figures are so nearly alike is a distinct triumph for the steam turbine; whatever allowances may be necessary—if any—on account of differences in running, as to stoppages or route, would not be likely to essentially affect the result. Both these vessels were built by Denny's, of Dumbarton. The model of the *King Edward* was made the subject of elaborate tank experiments, and we may feel sure that each design was framed to get the best efficiency under the conditions to be fulfilled.

The results of the season's running, financially and otherwise, have been so successful that it has been decided to build another boat of the same type. At present the Parsons Marine Steam Turbine Company have on hand the machinery for this vessel. She is, however, to be a larger and faster ship, her length being 20 feet more, and her speed 21 knots.

The Turbine Company have also in hand, at their works at Wallsend-on-Tyne, turbine machinery for three high-speed yachts. The first of these is a vessel of 700 tons, the hull and boilers of which are being built by Messrs. Alexander Stephen and Sons, of Linthouse, Glasgow. The steam-turbine machinery of this ship is designed to develop about 1,500 horsepower. She is to be classed at Lloyd's. The next vessel is of larger size, being about 1,400 tons, yacht measurement. The hull and boilers are being constructed by Messrs. Ramage and Ferguson, of Leith. She will be 260 feet 8 inches long between perpendiculars, and 253 feet long on the load-water line. The molded breadth will be 33 feet 3 inches, and the machinery will develop 3,500 horsepower. This fine vessel is being built for Mr. A. L. Barber, of New York, and will be classed at Lloyd's. The third vessel is in some respects the most interesting. She is for Colonel McCalmont, M. P., and, as might be anticipated, will have a decided sporting element incorporated in her design. She will be on what may be called the torpedo-boat style, and as the hull and boilers are to be constructed by Messers. Yarrow and Co., of Poplar, it may be assumed that the turbine machinery will be given every chance to appear to advantage. The length on the water line,

which is the same as between perpendiculars, will be 152 feet 6 inches, the molded breadth 15 feet 3 inches, and the tonnage 170 tons. This vessel is designed for a speed of 24 knots.

The Parsons Company have also in hand, and nearly completed, a torpedo-boat destroyer, which will have about the same speed as the *Viper*, but is designed to have a superior performance to that recorded of the latter vessel in regard to coal consumption at cruising, as well as at higher, speeds. We believe Mr. Parsons has been giving a good deal of attention to the question of coal economy, and it is anticipated that this new destroyer, which is not being built to the order of the Admiralty, will be more economical under both cruising and full speeds than any 30-knot destroyer in the Royal Navy.

It is highly satisfactory to find that one of the most striking developments in the history of marine engineering is being carried to a practical issue by private enterprize. Considering, however, that the only two turbine boats belonging to the fleet were lost through mishap entirely unconnected with the machinery—and remembering what remarkable results were obtained with these two craft—it is a little surprising that at present no vessel is in progress fitted with turbine machinery and built for the Royal Navy.—"Engineering."

EXPERIMENTS ON SPIRAL SPRINGS.*

By Chas. H. Benjamin,† M. Am. Soc. M. E., and Roy A. French.‡

The experiments described in the following paper were made under the direction of Mr. French, and the calculations are his. There is such scarcity of reliable data on spiral springs, their strength and elasticity, that it seems desirable to publish the results of these experiments. Our text books and our technical journals contain discussions and formulas, but very few data from which constants can be obtained to use in the formulas.

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* A paper presented at the annual meeting of the American Society of Mechanical Engineers.

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In the experiments to be described, an attempt has been made to determine the coefficient of torsional elasticity and the safe stress for different sizes of bar and different ratios of mean diameter of spring to diameter of bar. The following notation will be used:

P = load in pounds.
S = torsional stress in pounds per square inch.
G = coefficient of torsional elasticity.
D = mean diameter of spring in inches.
d = diameter of bar in inches.
H = height of spring in inches.
L = length of bar in inches.
x = deflection in inches with load P.

Then, by the usual formulas for tension and compression springs:

$$P = \frac{S\,d^3}{2.55\,D} \quad \textit{and} \quad x = \frac{L\,D\,S}{G\,d}.$$

The springs tested were all made of tempered steel and were open-coil, or compression springs. The results shown in the table were in every case obtained by testing a number of springs made as nearly alike as possible, and using the average loads and deflections for computation. Every spring was first closed solid, coil to coil, several times in a hydraulic press, to remove all permanent set; then placed in a Riehlé testing machine and tested for capacity and corresponding deflection.

To illustrate, take for an example group No. 1 in the table. This group consisted of 15 springs, 9.25 inches outside diameter and 17.25 inches free height before closing. The steel used was 1.3125 inches in diameter and 150 inches long before the ends were tapered. These springs were placed in the press one at a time, and closed coil to coil twice under the full capacity of the press, 75,000 pounds. The pressure was then removed, and upon measuring they were found to average 15.25 inches in height, showing a set of 2 inches. They were then closed twice more, but took no further set. A spring closed solid with 100 per cent. overload should take all its permanent set with two closings.

The springs were then placed in the testing machine and the load and total deflection measured. The average load necessary to close them was found to be 10,900 pounds, and the corresponding deflection was 7.0625 inches. When taken from this machine the free height was again measured, but they had taken no more set.

For substitution in the formulas we then have: $P = 10.900$, $d = 1.3125$, $D = 9.25 - d = 7.9375$, $x = 7.0625$, $L = 150$.

Substituting and solving for S and G:

$S = 97{,}500$ = the torsional stress in pounds per square inch when the spring is closed coil to coil, and $G = 12{,}500{,}000$, the coefficient of elasticity. Dividing the mean diameter of the spring by the diameter of the bar gives a ratio which will be called R, in this case equal to 6.05. Dividing the permanent set by the working deflection gives another ratio, which will be called Y. In this case, $Y = 0.283$.

In a similar manner were calculated all the results given in the table.

Additional notation used in table:

N = number of springs in group.
O = outside diameter in inches.
H = height before closing in inches.
H' = free height in inches after producing set.
H'' = height in inches when closed solid.
$s = H - H'$ = permanent set in inches.
$x = H' - H''$ = total action in inches.

The value given for G in most hand-books is 12,000,000. The larger values shown in the tables are doubtless due to the higher grade of steel used. The variation in values of G is probably due to differences in temper, although in some cases the chemical constituents of the steel may have varied slightly. The average value is found to be 14,700,000, which may be written 14,500,000 for convenience.

The proper stress is a more difficult thing to determine. A wide range of stresses was used in the springs experimented with. In each case the stress was that believed to be the best for the conditions under which the spring must work. In some few

TABLE SHOWING RESULTS OF TESTS OF SPIRAL SPRINGS.

Group.	Number of springs.	Outside diameter.	Mean diameter.	Diameter of bar.	Ratio $=\frac{D}{d}$.	Length of bar.	Height before closing.	Height after closing.	Permanent set $= H-H'$.	Height when closed.	Total action $= H'-H''$.	Ratio $=\frac{S}{x}$.	Load to close spring.	Coefficient of torsional elasticity.	Torsional or shearing stress.
	N	O	D	d	R	L	H	H'	S	H''	x	Y	P	G	S
1	15	9.25	7.9375	1.3125	6.05	150	17.25	15.25	2	8.8175	6.432	.311	10,900	12,500,000	97,500
2	20	6.625	5.375	1.25	4.3	80	7.125	7	.125	5.9375	1.062	.117	6,375	14,400,000	44,700
3	12	6	4.75	1.25	3.8	67	7.875	7.5	.375	5.875	1.625	.23	16,600	16,150,000	103,000
4	6	5.25	4.125	1.125	3.67	89	10.75	10.125	.625	7.625	2.5	.25	13,800	13,400,000	102,000
5	20	4.75	3.625	1.125	3.23	75	9.875	9.375	.5	7.25	2.125	.235	17,000	12,500,000	110,000
6	40	7.75	6.625	1.125	5.9	100	7.875	7.625	.25	5.5	2.125	.117	4,850	15,800,000	57,500
7	36	5	3.9375	1.0625	3.7	61	7.5	6.9375	.562	5.375	1.567	.36	12,000	14,400,000	100,000
8	64	5.5	4.4375	1.0625	4.18	101	11.125	10.6875	.437	7.625	3.062	.142	12,000	15,100,000	113,000
9	24	4.375	3.3125	1.0625	3.1	48	6.5	6.125	.375	5	1.125	.333	14,800	13,700,000	104,000
10	6	6	5	1	5	84	8.625	8.125	.5	5.625	2.5	.2	8,000	17,100,000	102,000
11	20	4.5	3.5	1	3.5	79	9.875	9.4375	.437	7.25	2.187	.201	12,500	14,100,000	111,800
12	16	4.25	3.25	1	3.25	49	6.5	6.125	.375	4.875	1.25	.3	13,100	13,800,000	109,000
13	36	4.75	3.75	1	3.75	37	4.5	4.125	.375	3.25	.875	.43	12,000	18,100,000	114,400
14	35	4.187	3.25	.9375	3.48	50	6.5	6	.5	4.75	1.25	.40	10,500	14,700,000	106,000
15	800	4.5	3.625	.875	4.15	57	6.375	6	.375	4.4375	1.562	.24	6,250	13,100,000	86,500
16	8	3.75	2.875	.875	3.28	41	5.375	5	.375	4.125	1.875	.43	10,800	18,100,000	118,000
17	24	4	3.125	.875	3.58	60	7.375	7	.375	5.4375	1.562	.24	8,650	13,900,000	103,000
18	40	4	3.125	.875	3.58	51	6.5	6	.5	4.625	1.375	.364	12,000	18,900,000	143,000
19	24	3.375	2.625	.75	3.5	62	7.25	7	.25	5.655	1.345	.186	5,250	13,500,000	83,500
20	8	5.75	5	.75	6.67	172	17.625	16	1.625	8.4375	7.562	.212	2,850	13,100,000	86,500
21	8	4.5	3.75	.75	5	84	8.5	8	.5	5.5	2.5	.20	4,000	15,200,000	91,000
22	12	3.5	2.75	.75	3.67	53	6.375	6	.375	4.625	1.375	.273	6,950	16,200,000	115,000
23	4	4	3.25	.75	4.33	44.5	5.75	4.6875	1.0625	3.0625	1.625	.655	6,500	15,400,000	127,000
24	24	3.5	2.875	.625	4.6	68	7.375	7	.375	4.6875	2.312	.162	3,250	13,600,000	97,500
25	100	3.25	2.625	.625	4.2	37.5	4.375	4	.375	2.8125	1.187	.316	4,225	15,500,000	116,500
26	100	3.25	2.625	.625	4.2	43	4.75	4.5625	.187	3.375	1.187	.158	4,000	16,700,000	109,500
27	200	3.5	3	.5	6	108	9.75	9.625	.125	5.8125	3.812	.032	1,250	12,900,000	76,500

cases, as in No. 18, it was necessary to use an abnormally high value to meet the conditions. This necessitated a special grade of steel, and great care in manufacture. Such a spring is not safe when subjected to sudden and heavy loads, or to rapid vibrations, as it would soon break under such treatment; if merely subjected to normal stress, it would last for years.

It will be noticed, by comparing columns S, Y and R of the table, that Y varies with both S and R for the same diameter of bar; that is, if R is constant, S and Y increase together, and if S is constant, R and Y increase together. There are some exceptions to this rule noted, but it is believed to be generally correct. This being true, a spring with its mean diameter small, as compared with size of bar, will allow a higher stress with less proportionate set than one of a larger mean diameter. An excessive set means injury to the material, and liability of failure.

Springs of a small diameter may safely be subjected to a higher stress than those of a larger diameter, the size of bar being the same. The safe variation of S with R cannot yet be stated. There is an important limit, however, which should be here mentioned. Springs having too small a diameter as compared with size of bar are subjected to so much internal stress in coiling as to weaken the steel. A spring to give good service should never have R less than 3.

The size of bar has much to do with the safe value of S; the probable explanation is this: A large bar has to be heated to a higher temperature in working it, and in high-carbon steel this may cause deterioration; when tempered, the bath does not affect it so uniformly, as may be seen by examining the fracture of a large bar.

The above facts must always be taken into consideration in designing a spring, whatever the grade of steel used. A safe value of S can be determined only by one having an accurate knowledge of the physical characteristics of the steel, the proportions of the spring, and the conditions of use.

For a good grade of steel the following values of S have been found safe under ordinary conditions of service, the value of G being taken as 14,500,000.

For bars below $\frac{3}{8}$-inch diameter:

$R = 3$ $S = 112{,}000$
$R = 8$ $S = 85{,}000$

For bars $\frac{7}{16}$ to $\frac{3}{4}$ inch in diameter:

$R = 3$ $S = 110{,}000$
$R = 8$ $S = 80{,}000$

For bars from $\frac{13}{16}$ to $1\frac{1}{4}$ inches in diameter:

$R = 3$ $S = 105{,}000$
$R = 8$ $S = 75{,}000$

METHOD OF FITTING LIGNUM VITÆ STRIPS TO STERN AND STRUT BEARINGS OF *OREGON*.

By Lieutenant H. G. Leopold.

In carrying out this work the method of procedure was as follows: The log was first sawed in the usual manner, as shown in

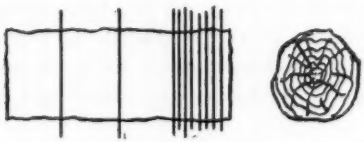


Fig. 1.

Fig. 2.

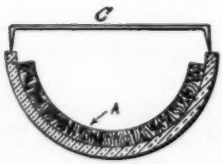


Fig. 4.

Fig. 5.

Figs. 1 and 2. A jig was then cut and rough machined, the strips secured in the jig and turned in an engine lathe to the proper diameter inside of the bushing. These strips were next

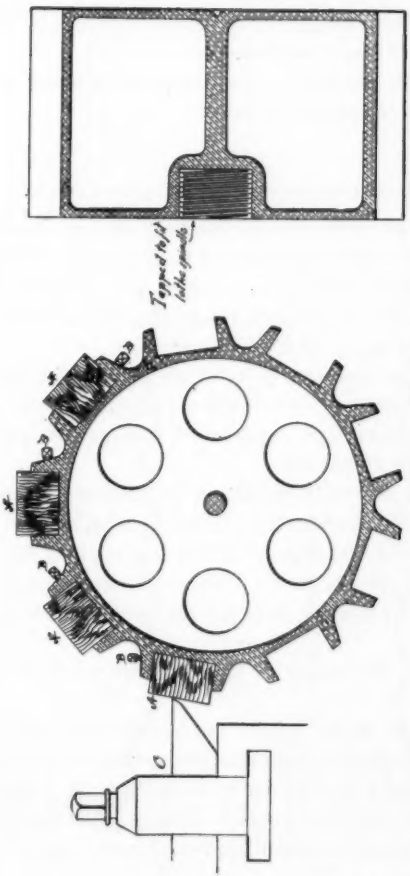


Fig. 3.

secured in a holding tool, as illustrated in Fig. 5, and surfaced on one side on a table planer, after which they were reversed and clamped to a gauge in the holding tool. In this manner all the strips were made uniform and an accurate fit.

The side of the wedge strips only required to be set to a tapering line and hand finished.

The jig was so proportioned as to admit of being used for different diameters within small limits.

OIL-FUEL BURNING ON THE PACIFIC COAST.

To those of the readers of the JOURNAL who are interested in oil fuel we offer the following extract from a letter on the subject:

"We have been adapting our boilers and furnaces to suit fuel oil, which we can now get from Bakersfield delivered at our works for 85 cents per barrel of forty-two gallons.

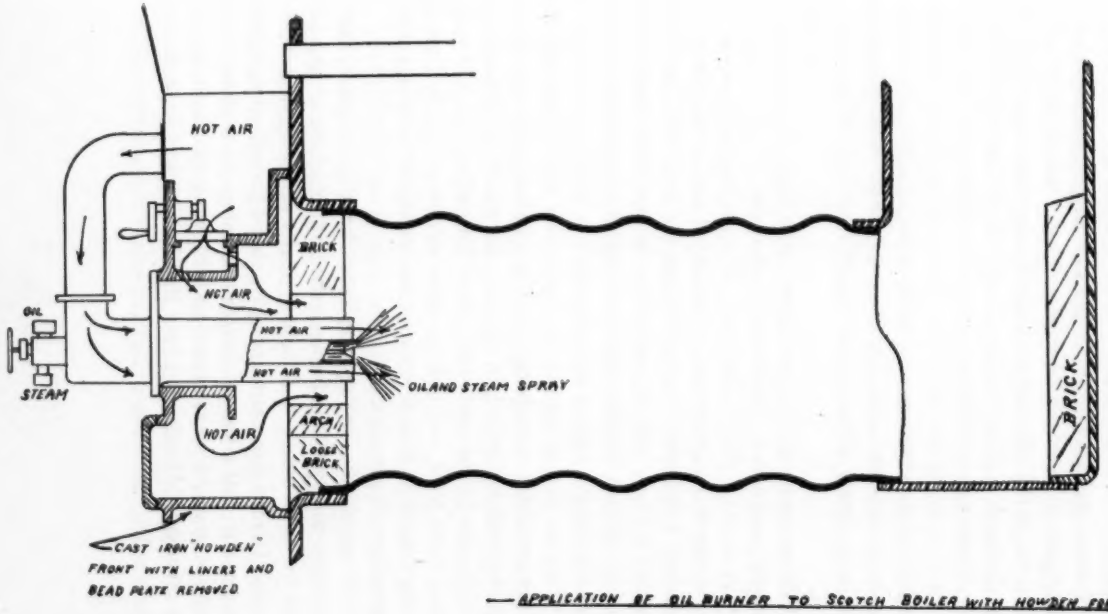
"The oil is an average of 16 degrees Baumé with asphaltum base, is quite limpid at 150 degrees Fahrenheit, but congeals at about 40 degrees enough to prevent it passing through the $\frac{3}{8}$-inch pipe of an ordinary funnel.

"If heated in pipes or tanks above 200 degrees it tends to separate and deposit carbon on the oil side of pipe, and will also do so if heated to about 160 degrees if the heat applied has a temperature, say=150 pounds steam. Therefore any heating to make this oil fluid for pumping is best done by using exhaust steam or warm water.

"I send you the result of two tests we made of our Scotch boilers:

"We removed all the grates and bridge walls and put a brick wall against the back connection sheet as a protection to the stay nuts, and inserted the burner in middle of the front of furnace, utilizing the Howden air ducts in front as they existed, with the addition of a pipe (6 inches in diameter) from hot-air duct directly to ell on burner.

"After trying various burners we found this one well adapted to the Howden or any forced-draft system, and it gives a large volume of flame, which from observation does not seem to have



— APPLICATION OF OIL BURNER TO SCOTCH BOILER WITH HOWDEN FORCED DRAFT —

NOTES

the risk to the boiler that some of the jet burners have. I send you a rough sketch of its application.

"As far as I have seen in the many burners and systems that I have examined, I think that the oil spray must meet the air for combustion and have room *for ignition* before touching the colder boiler plate or even the brick of a furnace, and I think that the efforts to jet the oil against a brick wall, under the supposition that the brick wall will be hot enough to aid raising the temperature of the flame in the furnace, are not likely to give the best results; certainly not with this heavy oil, as if not completely burned before touching the brick work, it will build up a carbonaceous deposit, somewhat like coke, on the brick work, which will burn slowly, after the oil supply is cut off, under a strong blast.

"We are using this burner in our large forge furnace very successfully, and also in the angle-iron furnace.

"We have another burner here, which is used with an air pressure of about 9 ounces, with *no* steam jet, and in the tests I made it showed a little more economy than the present burner, but we adopted the one now in use, as our boilers were fitted for the Howden system, and it would have taken quite a sum of money to change to the higher air pressure.

"This air burner requires for fan power and oil heating about 1½ per cent. of the evaporation of the boiler, while 4.1 per cent. was required by the other burner. Some of the jet burners I tried required *8 per cent.*, and I have it from engineers of stations whom I can trust, that only by close attention can the jet system be kept down to *6 or 8 per cent.*, and with the ordinary fireman it averages 12 per cent.

"At one of the large plants here the chief engineer cuts off the steam supply to the burner until a little yellow smoke comes from the smokestack, and finds a greater economy than when he lets the fireman use steam enough to burn the oil without smoke. He reasons that when no smoke is coming from stack then he does not know to what extent he is blowing too much steam up the chimney. He claims to me that he has cut his oil consump-

tion from 112 barrels per day to *90 barrels* by simply pinching the steam to the jets.

"The air burner referred to has a flattened nozzle. Air pressure of 9 ounces is introduced at the rear, where a damper is fitted for control, and passes partly over an internal tray with a wide lip with saw-tooth edge, over which the oil drips and is swept by the surrounding air pressure into the furnace. This, of course, is gas making in the shortest time and distance, and when adjusted gives a very complete combustion at a low cost of spraying.

"The blacksmiths and forge men have no difficulty in making good welding heats with this, in fact much prefer it to coal.

"I would sum up what I think is necessary in fitting up for oil as follows:

"A constant pressure of oil supply of a temperature of about 170 degrees. Pump discharge should have loaded escape valve connection to suction.

"Care must be taken in oil-supply pipe to have no gas traps, as the accumulation of gas and its occasional passage through the burner will make the flame flicker, and sometimes put it out.

"Care must be taken to get rid of the water in oil; this is best done by settling tanks and drawing the water off from the bottom of the tank.

"Care must be taken to get all valves and joints perfectly tight. Cock with triangular hole in plug is a better regulator than needle valves for oil, and can be cleared out readily if plugged.

"Air supply for combustion should surround and enter from behind the point of the burner, and not be admitted all over the full width of furnace front; and the size of this airhole surrounding the burner should be adjustable to some extent to suit the variable requirements of the burner.

"Where a battery of boilers is in use, the tendency of the fireman is to get one or two boilers evaporating more than the others. To obviate this, I have fitted thermometers in the base of smokestack or upper part of breeching, and instructed the men to try to keep the temperature as nearly equal as possible. Also, when

steam jets are used I have inserted a nipple between valve and burner, this nipple having a hole in it just large enough to pass steam suited to the requirements of the particular burner.

"Among the many patented burners there is little difference in their economy, and all depend for their economy on the cost of the spraying, which is left to the control of the firemen too often.

"But with none of these burners, either forced or natural draft, have I known the maximum power obtained from boilers equal to that which can be obtained from Scotch boilers with Howden's hot-air forced-draft system, and I question if it can be obtained in water-tube boilers either, only I have not had the opportunity to prove this in practice. However, I have one instance in mind with Scotch boilers using Welsh coal with the Howden system: When the plant was changed over to use oil, they failed to produce the total power, although the power was produced much cheaper, and they had a higher temperature in the smokestack with oil."

NOTES ON FUEL OIL FOR GENERATING STEAM.—"SUNLIGHT BURNER."

Feed water measured in tanks.
Steam for atomizing oil measured through a nozzle which was previously calibrated.
Fuel oil weighed.
Seven hours' test of a Scotch boiler, using fuel oil with Howden forced draft.
Boiler contained three furnaces.
Boiler contained 1,700 square feet heating surface.

Air heating surface of Howden system, square feet		1,350
One burner used in each furnace.		
Oil burned per hour, pounds		682.7
Total water evaporated from and at 212 degrees per pound of oil, pounds		14.7
Steam used for atomizing oil, per cent	2.5	
heating oil, per cent	.3	
blower, per cent	1.3	
Total steam used, per cent	4.1	
Net water evaporated from and at 212 degrees per pound of oil, pounds		14.1
Total evaporation per hour from and at 212 degrees per square foot of heating surface, pounds		5.9
Temperature of smokestack, degrees Fahrenheit		419
air for combustion, degrees Fahrenheit		250
oil, degrees Fahrenheit		136

TEST ON SAME BOILER, USING MORE OIL PER HOUR.

Oil burned per hour, pounds	983.8
Total water evaporated from and at 212 degrees per pound of oil, pounds	14.3
Net water evaporated from and at 212 degrees per pound of oil, pounds	13.7
Total evaporation per hour from and at 212 degrees per square foot of heating surface, pounds	8.3
Temperature of smokestack, degrees	485
for combustion, degrees	275
oil, degrees	157
Pressure of steam, pounds per square inch	153
oil, pounds	35
draft, average, inch	1

PARROTT BUILDING.

Kind of coal or oil used.	Lbs. water per hour from and at 212°.	Stack temperature, degrees.	Air temperature, degrees.	Lbs. coal per sq. ft. grate.	Lbs. water evaporated per sq. ft. H. S.	Lbs. water evaporated per lb. of coal or oil.
Wellington screenings	6,500	600	295	48	8.7	7.5
Cardiff (selected)	8,516	650	305	43	11.48	11
Cardiff (average)	7,200	650	305	43	9.7	9.3
Coalinga oil, 32° B*	7,000	660	315	...	9.4	15.75† / 14.18‡
Bakersfield oil, 14° B*	7,400	675	345	...	10	14.75† / 13.28‡

* Larkin burner, with steam atomizer. † Gross. ‡ Estimate net.

Single-furnace Scotch boiler, 740 square feet heating surface, fitted with Howden's hot-air forced draft, with 300 square feet air-heating surface.

The amount of feed-water was weighed; also the amount of oil and coal consumed.

The amount of steam used for atomizing was *not* measured, but from other sources we know that at low power it is not less than 4 per cent. and at maximum power will be about 10 per cent.

NEW METHOD OF BURNING LIQUID FUEL.

A new method of burning liquid fuel has been devised by Messrs. Muirhead & Coy, a firm of electrical engineers of Beckenham, London. It is called the hydroleum system, and by means

of it all descriptions of liquid hydrocarbons from petroleum to the various tars and tar refuse are consumed with an entire absence of smell and smoke. The burner comprises a combined feed of steam and oil, or refuse, and the vapor of these two is concentrated upon an incandescent fire brick, upon striking which the combined steam, by means of the intense heat, is divided into oxygen and hydrogen, and these combining with the carbon are ignited and passed through the boiler. So perfect is the combustion, and so intense is the heat that is generated, that a considerable economy is effected in the consumption of the fuel for boilers of every description. Tests with a 50-horsepower Hornsby boiler have shown that fifteen pounds of water are evaporated by the consumption of one pound of tar refuse, whereas with the same quantity of steam coal only nine pounds of water are evaporated. The Admiralty have examined the process and intend to experiment with it in the Navy.—"Scientific American."

TRIAL TRIP WITH LIQUID FUEL-BURNING APPARATUS.

The *Trocas*, one of the Shell Trading & Transport Line vessels, equipped with liquid fuel-burning apparatus, was given a trial trip recently of great interest. The trial took place off the mouth of the Tyne and was attended by about eighty of the leading ship owners and ship builders. There were also present representatives from the two great German lines, Hamburg-American and North German Lloyd, as well as several engineers from the Admiralty and representatives of Lloyd's register and Bureau Veritas. The apparatus with which the *Trocas* is furnished consists of pumping and filling arrangements for converting the fore and after peaks, the fore and after cofferdams, and the ballast tanks underneath the engines and boilers, into liquid-fuel tanks, thus turning to account spaces hitherto quite useless either for cargo or bunkers, and making them serve for the storage of the vessel's fuel, leaving free for other purposes, if required, the ordinary coal-bunker space. In the *Trocas*, which is an oil tank steamer as well as a general cargo vessel upon the system peculiar to Messrs. Samuel's Shell Line steamers, it will be when carrying

general cargoes homewards from the East that the additional space will be most valuable; but in the case of vessels always carrying general goods a portion at least of the bunker space will be available for cargo when the ballast tanks and peaks are utilized for storing the fuel.

The visitors were shown a large scale drawing, placed in a conspicuous position on the deck of the steamer, of all her machinery, including sections of the boilers and furnaces, and including also sectional drawings of the sprinklers or burners, and actual samples of the burners themselves. The liquid-fuel apparatus for filling and emptying the peaks, ballast tanks, and cofferdams is simple and obvious. Turning now to the furnaces, their appearance does not differ very materially from the ordinary arrangement of furnaces for burning coal. The fire bars are left in place and are the same. The bridge of fire brick at the end of the furnace is in the same position, but is somewhat more heavily bricked, and the additional interior arrangements of the furnace appear to consist of an arch of fire brick immediately over the bridge, and a lining of fire brick at the back of the combustion chamber extending about as high as the middle row of tubes, and intended to receive the impact of the flame as it rushes through the furnace under the impetus of the steam and oil jets. These jets are produced by two tubular injectors, each of about 1½-inch internal diameter, with annular openings adjustable by ordinary hand wheels on the Rusden and Eeles' system for the steam and oil, the inrush of the steam breaking up the oil into particles like rain, and facilitating its immediate conversion into flame. The fire bars are protected against the strong heat by having broken fire brick upon them to a depth of 6 or 8 inches. The furnace fronts and the fire doors are very similar to those of ordinary pattern, excepting that there are three circular holes in each front, two for the reception of the injectors, and one a sight and air hole. The injectors themselves swing upon jointed pivots, admitting of the passage through them of the steam and oil as required.

The liquid fuel is pumped from the main receptacles already mentioned to settling tanks which are placed in the 'tween-decks

some 20 feet or more above the level of the fires. These settling tanks are disposed upon the patented arrangement known as the Flannery-Boyd system, in which they are capable of alternate use or of assisting each other in separating water from the oil before it is allowed to enter the furnace. The liquid fuel, after being pumped into these receptacles by pumps in the stokehole, and after being freed from any water, is allowed to fill by gravity through pipes to the swivel-jointed injectors already described, and the action is complete. The whole apparatus is remarkable for its simplicity, and was pronounced by all the engineers on board to be freer from complication and multiplicity of parts than anything which had previously been seen, although some fifty steamers have been fitted with liquid-fuel apparatus by the Wallsend Slipway & Engineering Company, which executed the contract on the *Trocas*, and although there are many other steamers running with liquid-fuel apparatus which have been fitted by other engineering firms.

The trial was more of a demonstration than a scientific experiment to ascertain data, the time allowed being much too short for any reliable figures to be obtained. The vessel got under way at 12·30 P. M., and steamed until 3 P. M. at ordinary voyage speed of about 9½ knots, making 9.9 knots on the measured mile. At 3 o'clock the visitors were invited to specially enter the stokehole for the purpose of witnessing the ease with which the fuel apparatus could be changed to coal burning. The forward boiler—there are three boilers in the *Trocas*, each with three furnaces—was first taken in hand, the flame being put out by simply closing the valves, the fire brick which had hitherto protected the bars being raked into the stokehold, coal being then laid upon the bars without the usual preparation of chips and shavings. The fire doors were immediately closed, the oil and steam again turned on and lit for the purpose of, in their turn, igniting the coal.

The first boiler was steaming under way with coal in 9½ minutes from the time it had been shut off from steaming under oil. The same process was applied to the other two boilers in their turn, and the vessel was continuing her way under coal in

just half an hour from the time she temporarily ceased to be steaming on oil. The engines were not stopped, but were slowed down from about sixty to fifty revolutions, and the simplicity of the apparatus was still further demonstrated and admitted by the scientific gentlemen who were present. Whilst the vessel was under oil the flame was observed to be very clear and intensely hot, and of course of almost absolute steadiness, the steam not varying but being so plentiful that the safety valves blew off from time to time. There seemed little doubt that there was power enough in the boilers to enable one boiler to be laid off and the engines to be driven at their ordinary speed by the two remaining boilers.—" Marine Review."

MISCELLANEOUS NOTES.

CARE OF MACHINERY IN THE ENGLISH NAVY.—The Admiralty have quite recently decided—in connection with the care and maintenance of certain of the more important portions of the machinery supplied to British men-of-war—to make a change which may possibly have far-reaching results. The engineer officers of a ship have heretofore been required to undertake the charge of, and to be responsible for, the maintenance in a state of efficient working order, of the following, among other parts of the machinery: All steam and hydraulic pumping and other engines for loading and working the guns, for supplying ammunition and for turning turret barbette platforms and other forms of gun mountings; all Whitehead and other torpedoes, and submerged tubes and gear; and all electric-light engines and dynamos. It has also been a special instruction to the captains of ships in regard to the torpedoes, that " the dynamos and engines for driving them are in charge of the engineer officer, who is responsible for their mechanical and electrical efficiency." The result of this arrangement, by which one man was responsible for the effective working of a machine and another for its efficient use, was not always happy, and somewhat conducive to friction. Moreover, it had a distinct bearing on the burning question of the position of the engineer officers of the Navy, and has been

one of the principal arguments used in the rather heated discussion which has arisen out of that matter. By the new regulations all this is to be altered. The gunnery lieutenant is in future to take charge of all the hydraulic machinery which is in any way connected with the gun mountings, while the torpedo lieutenant is to be responsible for the dynamos, motors, torpedoes, and all the fittings which have to do with torpedo armament. All these matters have thus far been removed from the care and control of the engineer officer, who will now be simply required to provide steam to work the dynamos and hydraulic engines.—"Engineering."

VANADIUM STEEL.—In a paper read before the Manchester section of the Society of Chemical Industry, Mr. H. Procter Smith gives some figures showing the effect of adding to steel or iron a small percentage of vanadium. Thus, on comparing a tool steel having the composition C, 1.2 per cent.; Si, 0.26 per cent.; S, 0.02 per cent.; P, 0.02 per cent.; Mn, 0.07 per cent.; and vanadium, 0.53 per cent., with one of similar composition, but without the vanadium, and with but 0.07 per cent. of Si, the following results were obtained:

	With vanadium.	Without vanadium.
Tensile strength, tons per square inch	72.42	62.50
Elastic limit	50.75	35.70
Elongation, per cent. on 2 inches	6.25	8.00
Reduction of area, per cent.	5.90	7.80

On testing for cutting power on hard chilled iron, vanadium steel, tempered to a deep straw, proved equal to quenched and untempered tungsten steel. In other experiments in which vanadium was added to malleable iron and mild steel the following results were obtained:

	Tensile strength, tons per sq. in.	Elongation per cent.
Malleable iron	24.5	19
Ditto, + 0.50 per cent. V. (forged)	39	12
Ditto, + 0.50 per cent. V. (annealed)	33.7	32
Mild steel	30	17
Ditto, + 0.50 per cent. V	61	14
Ditto, + 0.50 per cent. V. (annealed)	45	20

Vanadium therefore appears to increase the tensile strength of steel; and vanadium steels, whilst very hard when hardened, are very soft when annealed.

HOT-BATH TEMPERING.—A novel method of steel tempering is being used in connection with the gas furnace by certain manufacturers, whereby the temper to which the work is to be drawn is reduced to an absolute certainty. The crucible of a crucible gas furnace is filled with melted beef tallow, and this tallow bath may be maintained at almost any temperature required for drawing tempers, as tallow is capable of taking very high temperatures. The temperature of the bath is determined by a suitable pyrometer, as Le Chatelier's electrical pyrometer, in which the temperature may be read at some distance from the furnace, and its temperature may easily be varied and regulated by adjusting the gas flame in the furnace. In this way the exact heat required to draw the temper the desired amount may be definitely obtained, which eliminates the element of guesswork from the process. For instance, if it is desired to draw the temper on milling cutters, or taps and dies, to their required straw-yellow temper, all that is necessary is to adjust the heat of the bath to about 460 degrees Fahrenheit, as indicated by the pyrometer, which is the temperature to which hardened steel must be drawn to give the straw-yellow temper, and then dip the pieces in which the temper is to be drawn into the bath. They need only be left in the bath for a length of time sufficient for the heat of the bath to thoroughly penetrate the work, although if the temperature of the bath is kept constant the work may be left in for an indefinite time without the least danger of running the temper too low. The work to be tempered may be suspended in the bath by means of a wire basket, and all parts of the pieces immersed, whether of thin or thick section, will be evenly heated, thus ensuring an even temper, or degree of hardness, throughout. This method offers the great advantage that drawing temperatures which have been found to give good results may be repeatedly employed on particular work with absolute certainty of uniformity of results.—"Machinery."

STANDARDIZATION OF EXTRA HEAVY PIPE FLANGES.—Steam pressures varying from 100 to 250 pounds pressure entered into engineering practice about the year 1889. For pressures less than 100 pounds there had long existed confusion regarding standards for flanges of pipe, fittings and valves. A schedule of standard flanges was adopted July 18, 1894, by a committee of the Master Steam and Hot Water Fitters' Association, a committee of the American Society of Mechanical Engineers, and the representatives of the leading valve and fitting manufacturers of the United States. As the use of high steam pressures became more general there came into existence so many different diameters, thicknesses, drilling circles and number of bolts for flanges on fittings, valves and pipe for extra heavy pressures that manufacturers could not safely keep stocks of goods, and mill architects and engineers were greatly delayed at times in making up specifications for contemplated work on account of time taken to find out what the different manufacturers could or would furnish.

Recognizing the need of a standard for extra heavy flanges, an invitation was issued to the leading valve and fittings concerns of the country to meet and consider this subject. In response to this invitation several of the largest concerns sent representatives to a meeting at New York City, April, 24, 1901. At that meeting a committee was chosen to formulate a standard.

The committee had various sessions and submitted to the manufacturers interested the following recommendations and schedule for standard at a meeting held in New York City, June 28, 1901:

1. Multiples of four for drilling.

2. Drilling should straddle axis.

3. Bolt centers not to exceed $3\frac{5}{8}$ inches except on $2\frac{1}{2}$-inch size. Committee at first proposed $8\frac{5}{8}$-inch bolts, but sample elbows and flanges were drilled and bolted together and it was found that $8\frac{5}{8}$-inch bolts interfered with inserting bolts.

4. Distance from center of bolt to edge of the flange should always equal or exceed the diameter of bolt plus $\frac{1}{8}$ inch for 9-

inch valves and under, and diameter of bolt plus not less than $\frac{1}{4}$ inch for sizes larger.

The bolt circle diameters as above stated will allow the use of calking recess on pipe flanges provided such device is specified.

Size of pipe.	Diameter of flange.	Thickness of flange.	Diameter of bolt circle.	Number of bolts.	Size of bolts.
inches.	*inches.*	*inches.*	*inches.*		*inches.*
2	$6\frac{1}{2}$	$\frac{7}{8}$	5	4	$\frac{5}{8}$
$2\frac{1}{2}$	$7\frac{1}{2}$	1	$5\frac{7}{8}$	4	$\frac{5}{8}$
3	$8\frac{1}{4}$	$1\frac{1}{8}$	$6\frac{5}{8}$	8	$\frac{5}{8}$
$3\frac{1}{2}$	9	$1\frac{3}{16}$	$7\frac{1}{4}$	8	$\frac{5}{8}$
4	10	$1\frac{1}{4}$	$7\frac{7}{8}$	8	$\frac{5}{8}$
$4\frac{1}{2}$	$10\frac{1}{2}$	$1\frac{5}{16}$	$8\frac{1}{4}$	8	$\frac{5}{8}$
5	11	$1\frac{3}{8}$	$9\frac{1}{4}$	8	$\frac{5}{8}$
6	$12\frac{1}{2}$	$1\frac{7}{16}$	$10\frac{5}{8}$	12	$\frac{5}{8}$
7	14	$1\frac{1}{2}$	$11\frac{7}{8}$	12	$\frac{5}{8}$
8	15	$1\frac{5}{8}$	13	12	$\frac{5}{8}$
9	16	$1\frac{3}{4}$	14	12	$\frac{5}{8}$
10	$17\frac{1}{2}$	$1\frac{7}{8}$	$15\frac{1}{4}$	16	$\frac{5}{8}$
12	20	2	$17\frac{3}{4}$	16	$\frac{5}{8}$
14	$22\frac{1}{2}$	$2\frac{1}{8}$	20	20	$\frac{5}{8}$
15	$23\frac{1}{2}$	$2\frac{3}{16}$	21	20	1
16	25	$2\frac{1}{4}$	$22\frac{1}{2}$	20	1
18	27	$2\frac{3}{8}$	$24\frac{1}{2}$	24	1
20	$29\frac{1}{2}$	$2\frac{1}{2}$	$26\frac{3}{4}$	24	$1\frac{1}{8}$
22	$31\frac{1}{2}$	$2\frac{5}{8}$	$28\frac{3}{4}$	28	$1\frac{1}{8}$
24	34	$2\frac{3}{4}$	$31\frac{1}{4}$	28	$1\frac{1}{8}$

The schedule presented was unanimously adopted by the manufacturers present, and Jan. 1st, 1902, was the date set for adoption of the same.—"Sibley Journal of Engineering."

Liquid Steel Compression.—An interesting method for compressing liquid steel, so as to prevent the formation of pockets and flaws during manufacture, has recently been patented in the United States by M. Henri Harmat, of St. Etienne, France. The compression takes place in a mold of frusto-conical shape, with a movable bottom, and a cover fitted inside. Into this mold, which is placed in a vertical position, with its greater diameter at the bottom, the liquid steel is poured and the movable bottom is pressed upward while the cover is pressed downward, though

with less force than that acting upon the bottom. By this arrangement lateral expansion is avoided, because the metal, while the contraction becomes more accentuated and as the ingot mold expands, is pushed towards the smaller base of the conic mold and is constantly pressed against its walls, flowing parallel to the axis of the cone. At the same time it secures the laminating, or drawing, of the steel, which, in consequence of the pressure exerted upon its larger basis, slides axially, not only pressing against the walls, but restricting and diminishing its section in proportion to the pressure that forces it to penetrate more into the narrow portions of the conic mold. Thus, by abolishing lateral expansion and replacing it by the drawing of the metal, the formation of pockets and the tendency of cracking are avoided. The pressure required in this process is not very great, because it is aided by the conical shape of the ingot mold, while the time during which this pressure is to be continued varies with the kind of steel treated, depending on its greater or lesser tendency to crack, and with the mass under treatment; but it need not be greater than the time required for completing the cooling of the ingot.—"American Machinist."

IRON AND STEEL.—INGOT MAKING.—An improvement in the final operations of the process of ingot making has recently been patented, and is said to have given perfect satisfaction during practical tests. Like that of most of the successful innovations of recent times in manufacturing methods, its object is to reduce to a minimum human participation in the actual work, and to render it possible for every detail to be automatic. Ere the alteration introduced by this new device was made, the process of ingot making was quite satisfactory during the earlier stages—*i. e.*, until the ingots, after their passage between the reducing mills, had been reduced to a cross-section so small as to require in being turned the assistance of attendants, who, by means of tongs, supplemented the action of the mechanism. The improved device permits the ingot to be turned even when greatly reduced, and renders the process automatic practically until the ingots have received their finish. This is accomplished

by a very slight change, consisting in providing the inner vertical side of the usual stationary horizontal side plates with a number of projections, or lugs. After the ingot has been turned by the usual means and reduced to the size in which it is no longer easily treated in the same way, these lugs come into play. The reduced ingot is first moved laterally so as to bring the outer upper edge thereof under the projection. The manipulations are then adjusted to bring about their upper corners under the inner bottom corner of the ingot, so that when they are raised that side of the ingot will likewise be raised and will make one-fourth of a revolution. After the ingot has thus been turned, the manipulators are operated to move it again laterally into line for the next reduction, and so forth. This arrangement has not only given complete satisfaction where it has been tried, as regards accuracy and certainty, but, by rendering unnecessary the presence of attendants, has resulted in a considerable saving of time and labor.—"American Machinist."

THE NEW BOILERS for the *North-West* and *North-Land* will be built by the Lake Erie Boiler Works, at Buffalo. They will be of the Scotch type and will be 12½ feet in diameter and 12 feet long. This means that the Belleville water-tube boilers will not be adopted on any more lake steamships.

A TORPEDO-BOAT STATION AT NORFOLK, VA.—A dispatch from Norfolk, Va., says that the report current during the summer months that the St. Helena property, or a portion of it, would be made a torpedo-boat station, seems about to be verified as correct. Contracts have been made for the dredging of seven slips and the construction of the necessary piers. Six of the slips or docks are to be each 296 feet in length, and one will have a length of 4,000 feet. They will all be dredged to afford a depth of 15 feet at low water. The piers which separate these docks will be about 24 feet in width. The work will cost $109,000, and its purpose is to afford berths for the torpedo boats of the Navy. Comparatively speaking, these boats are delicate affairs, and require such care and maintenance that it

will be necessary to take them from the docks about once a month. As a further means of protecting them, it is the purpose of the Department of Yards and Docks to build sheds or roofs over these docks as soon as the necessary appropriation can be secured.—" Marine Review."

Wireless Telegraphy in the Navy.—Steps have been taken by the Navy Department toward the adoption of wireless telegraphy at sea. Admiral Bradford, of the Bureau of Equipment, has asked that the armored cruisers of the *Pennsylvania* class have their masts and rigging so arranged that the wireless system can be introduced. This will necessitate the lengthening of the masts of the ships and the insulation of the metal rigging by the use of hemp covering for halyards. It is intended to get test sets of instruments of the various wireless systems now being operated. Thus far, the Navy Department has not adopted definitely any system, but the construction of the new ships is regarded as a preliminary to the adoption of a system whenever its practicability is established fully. The British Navy already has a number of its ships equipped with the wireless system, but this is the first move on the part of the American Navy to make use of a wireless plan.

An Admiralty Contract.—Messrs. Swan and Hunter, Limited, Wallsend-on-Tyne, have secured a contract for the construction for the Admiralty of a pontoon dock which will be utilized for the docking of His Majesty's ships at Bermuda. The dock will, it is stated, be the largest pontoon dock in the world. The principal dimensions are: Length, 550 feet; breadth, 126 feet; depth, 56 feet; lifting capacity, 16,500 tons.

Packing for Tubes of Belleville Boilers.—Naturally the Admiralty wishes to save its reputation, if possible, by proving that the Belleville boilers are not worthless. To this end experiments are being carried out which it is hoped may prevent leaky tubes. It is said that a satisfactory remedy has been discovered. The joints of the tubes are being packed with a special form of asbestos which prevents all leak-

age. Should this answer the purpose desired, the vessels fitted with Belleville boilers will not lie under any disadvantage. The matter is so important that it is not surprising to learn that the staffs of the Admiralty laboratories are busy in testing the value of the improvement.—"Naval and Military Record," December 12, 1901.

WATER-TUBE BOILERS.—The French government has recently been experimenting with the Montupet water-tube boiler, but the results obtained have not been published. One important feature of this type of boiler, however, has, according to the "Mittheilungen aus dem Gebiete des Seewesen's," become known as the result of previous trials, namely, that the tubes of the Montupet boiler can be removed and replaced in a remarkably short space of time. On one occasion, during a trial lasting over four hours, the fires were reduced, the steam pressure lessened, the boiler emptied and a tube removed. All this was accomplished in a quarter of an hour. Upon the tube afterwards being replaced, the steam pressure was restored almost instantly. The total interruption, from the reduction of the fires to the restoration of the boiler to its proper working condition, occupied 40 minutes, of which less than ten sufficed for removing and replacing the tube. When the fires were out and the boiler had cooled, thirty-two tubes were removed within an hour and twenty minutes.—"Fielden's Magazine."

THE U. S. FLOATING DOCK, at Algiers, La., was successfully tested on January 6. The battleship *Illinois* was lifted entirely out of the water in 1 hour 57 minutes, whereas the contract allowed 2 hours 40 minutes for this work. All of the machinery worked satisfactorily.

AT THE INSTANCE of Rear Admiral Melville an additional estimate of $20,000 has been presented for tests of liquid fuel for naval purposes. The Bureau of Steam Engineering desires to carry on an extended series of tests to find out the value of this combustible for naval purposes. The chemical composition of the Texas yield is different from that of the Pennsylvania and

Ohio districts, and therefore it may be possible to burn the Texas product, although comparatively little commercial success has been secured in burning the northern fuel. In general one pound of liquid fuel should evaporate 50 per cent. more water than a pound of excellent coal, and the small sum required for these tests is certain to bring a good return in giving the Navy Department information as to whether or not it will be possible to utilize this combustible for warship purposes.—"Army and Navy Journal."

COALING SHIPS AT SEA.—Last week the Temperly-Miller apparatus for coaling ships at sea under way was tried at Portsmouth Harbor with the vessels stationary. A rate of 37 tons an hour was reached. Various naval wiseacres of the non-progressive order spent the rest of the week in demonstrating that this could not be done at sea. On Monday there was a proper sea trial, and 36 tons an hour was reached—practically the same as the harbor result, and one that practice, if past coaling experiences go for anything, will double. However, this matter is too important to be dealt with in a paragraph, and we shall later on be dealing with it elsewhere in detail. On Wednesday, the 5th, at the official trials, 30 tons was taken for three hours' running, and 40 tons taken in one hour. Everything was a complete success.—London "Engineer," February 7, 1902.

THE VALUE OF SUPERHEATERS.—Among the Foreign Abstracts in the Proceedings of the Institute of Civil Engineers, we find the following data, referring to the use of superheaters, which, we believe, will be of interest to our readers. The value of superheaters, says the author of the summary, depends mainly on the fact that by their use an increase is effected in the volume of the steam, and hence, also, in the work obtainable from it, while the expenditure of heat is increased to a proportionately smaller extent. In a table based on the increased volume of the steam, and showing the percentage saving of heat when working at various pressures and with various degrees of superheating, the figures obtained vary from 0.4 per cent. for a pressure of

fourteen atmospheres, and a temperature of superheating of 200 degrees centigrade up to 27.9 per cent. for a pressure of four atmospheres, and a temperature of 440 degrees centigrade do not, however, agree with those actually yielded in practical working, owing to several secondary actions, some of which increase while others diminish the calculated saving. One of the most important of such secondary influences is the degree of supersaturation of, or amount of water contained in, the steam, the condensation of this water on the cylinder walls and the consequent dissipation of heat being obviated by superheating. Further, the saving in fuel is not so great as the saving of heat due to the superheater, since such circumstances as the imperfect using of the fuel and the walling-in of the superheater here come into play. With regard to the latter point, in the case of water-tube boilers there is a space directly above the tube system suitable for receiving the superheater, and to this, and also to the fact that water-tube boilers often produce much wetter steam than is the case with Cornish boilers, is due the greater success of the superheater when used in conjunction with the water-tube boiler.

The construction of superheaters, the guiding principle of which is to obtain the largest possible heating surface compressed into a minimum of space, has followed mainly two principal forms, the older one being the cast-iron ribbed superheater, while the more modern pattern consists of narrow wrought-iron tubes. When possible, it is undoubtedly preferable to arrange the superheater in a vertical position, in which it is less liable to collect ashes and soot, which are besides more readily cleared away. The methods of regulating the temperature of superheating are also treated of.

SHIPS.

UNITED STATES.

Report on Torpedo Boats and Destroyers.—The following report was published in the "Army and Navy Register" of February 1:

NAVY DEPARTMENT,
Washington, D. C., November 25, 1901.

SIR: In obedience to the Department's order, and your instructions, and the instructions contained in the Bureau's letter No. 2403–A–25, of the 11th instant, directing us to inspect the torpedo boats and torpedo-boat destroyers under construction by various contractors on the Atlantic coast, we have the honor to report that we have visited the various works where these vessels are being built.

In addition to matters of detail which have come under our notice, some general observations which we deem of importance have been made. These may be considered under two principal heads: First, as to the financial conditions under which these vessels have been built; second, as to the difficulties of obtaining the material results expected. With the exception of two vessels (the *Stringham* on this coast and the *Goldsborough* on the Pacific coast), all these vessels were contracted for under the naval appropriation act approved May 4, 1898, for sixteen destroyers and twelve torpedo boats. The act provided that the destroyers should be of about 400 tons displacement each, and the torpedo boats of about 150 tons displacement each, and limited the total cost of the twenty-eight vessels to $6,900,000; it was further provided that not more than five of the destroyers and not more than four of the torpedo boats should be built in one yard or by one contracting party. All these vessels were required to have the highest practicable speed. Bids were invited on designs prepared by the Department and also on the bidders'

own plans. It was obviously the intention of Congress, in limiting the number of boats to be built by one contracting party, to distribute the work among a number of contractors, for various reasons of policy which appear sufficiently obvious. That this was thoroughly understood is shown by the fact that none of the contractors bid for more than four destroyers, with the exception of the Maryland Steel Company, which bid for five destroyers, but which in the end was awarded only three.

The recommendations of the Board on Construction with reference to the awards are contained in its second endorsement of September 9, 1898, on the Department's letter No. 6095–98, of September 1, 1898. The final awards made by the Department differed from the recommendation of the board only in that the Maryland Steel Company was given three destroyers instead of four, and that no torpedo boats were given to the Herreshoff Manufacturing Company. The destroyer not assigned to the Maryland Steel Company and one of the torpedo boats not assigned to the Herreshoff Manufacturing Company were given to the Gas Engine and Power Company, and the other torpedo boat refused to Herreshoff was awarded to the Columbian Iron Works.

Owing to a number of circumstances which need not be detailed here, these torpedo vessels authorized by the above mentioned act (with the exception of the three torpedo boats built by the Bath Iron Works, and two of the three by the Wm. R. Trigg Company), have not yet been accepted by the Government, and those that were accepted have only within the past few months passed their acceptance trials.

We were impressed by the evident sincerity of statements made by the contractors, which were practically universal, that the actual cost of labor and material expended by them on these vessels, not including general expenses, was in excess of the actual contract prices for them.

With the exception of the Bath Iron Works, which bid on its own designs, and the Columbian Iron Works, which subsequently went into the hands of a receiver, none of the contractors had previously completed torpedo vessels. At the time the contracts were let the Gas Engine and Power Company had the torpedo

boat *Bailey* under construction but were not far enough advanced with her to have gained valuable experience in the matter. The torpedo boats previously built had been generally of much smaller size and much lower requirements as to speed, and it is believed that those who built them (except, perhaps, the Herreshoff Manufacturing Company), had had considerable difficulty in their completion. The building of successful torpedo vessels having the "highest practicable speed" is an occupation that requires designing talents of a high order and prolonged experience in construction. There are comparatively few successful builders of torpedo vessels in the world, but the attempt was made in this country to rival the best results attained abroad with designs which were not based on the known results of a large number of previous vessels and by builders whose knowledge and experience were of a limited character.

At the time these contracts were taken these contractors evidently thought that the Department's designs or their own would be entirely adequate to fulfill the program laid down without difficulty, and they apparently went into the contracts with a light heart. As above stated, their experience, now that these vessels are approaching completion, shows that the difficulties of fulfilling the requirements have been enormous, and the cost to the contractors very largely in excess of the contract prices. As a number of these contractors have comparatively small plants and capital, it is our opinion that if harshly dealt with they will undoubtedly be forced to the wall, and two concerns, the Columbian Iron Works and Wolff & Zwicker, have already reached that position.

The situation is further complicated by the probability that a number of these vessels will fail to obtain their contract speed, or even that lower speed which, deducting penalties, allows them to be accepted at all. Under these conditions the contractors universally seem very much depressed, and from their conversation it would appear that while no concerted action has been taken up to the present time, they will in all probability appeal to Congress for relief.

The grounds for this action which have been outlined by them

in conversation are various, but the one which nearly all adopt as a basis for the claim is that they were led to believe that the plans and specifications furnished by the Government were adequate to achieve the results contracted for. That that is not the case is now evident and is due to a variety of causes. All the vessels built on the Department's design that have been tried are greatly over weight, and they all appear subject to excessive vibrations, causing breakdowns when the machinery is running at high speed. The weights allowed in the designs required the most careful study of details and the omission of everything non-essential to keep within the allowance, and it is doubtful, even with the most careful supervision, whether some excess would not have occurred, though doubtless many weights are in excess of those upon which it would have been feasible to design details of hull, fittings and machinery. Moreover, the constant tendency to add additional things for convenience or comfort produces a peculiarly disastrous effect on these extremely light vessels in which every particle of excess weight becomes a most serious handicap to the attainment of the required speed.

The question of vibration on vessels which have very high-speed engines requires the most careful consideration of structural arrangement to secure combined strength and lightness and a prolonged study of the balancing of the engines. That these matters have not been sufficiently attended to is obvious from the results so far obtained.

The contractors feel, with some reason, that, as they bid on Department designs, or, in some cases, on bidders' designs closely akin to the Department's designs, they are not responsible for the failure to achieve results aimed at, and they all insist upon their good faith in endeavoring to carry out the Department's wishes.

Another ground advanced for relief is the statement that large advances took place in the price of materials shortly after the contracts were awarded, amounting to 60 per cent. in some cases. Another ground is that the expense of the repeated trials, resulting in repeated failures, has enormously enhanced the cost. Furthermore, some of the contractors maintain that they were not at liberty to carry out their own designs and ideas; that they were

hampered by the inspectors; that had they been free to do as they pleased they would have achieved the results called for. It is difficult to state how much truth there is in this latter contention, but it has been obvious that, in many cases, the contractors relied upon the inspecting officers to furnish information for the working out of the details of these vessels.

As has been stated above, torpedo-vessel building is a special business. Up to the time these contracts were let (including the *Stringham*, *Goldsborough*, *Bailey* and *Farragut*) the only concerns that may be said to have achieved success or to have had any real experience in this line were the Herreshoff Manufacturing Company and the Bath Iron Works. The former had at its command the personality of one of the members of the company who is world-famous for work in this general line, and the Bath Iron Works purchased their knowledge and experience before they started out on such work, having at their disposal all the accumulated knowledge of the celebrated French builder Normand, and moreover, having sent a very capable employe abroad to study a long time in the works of M. Normand, there acquiring not only the theoretical but practical knowledge of all the details of construction of both hulls and machinery. The *Dahlgren* and *Craven*, built by the Bath Iron Works, are practically copies of the latest French vessels built by M. Normand, at the time of their design. Of the torpedo vessels authorized by the act of May 4, 1898, the three built by this firm, the *Bagley*, *Barney* and *Biddle*, have machinery practically identical with that of the former two, but a larger hull; the other details of construction are practically identical. These three boats just mentioned have come out nearly within their designed weight, and above the contract speed, but it is believed that, while the contractors probably did not lose money on these vessels, their profits were very small indeed. It is believed also that at the present time the employe who has charge of this character of work in their establishment is among those in this country best fitted for the designing and constructing of torpedo vessels.

The remaining two boats already accepted are the *Shubrick* and the *Stockton*, built by William R. Trigg Company, on the

Department's plans. These boats were tried stripped of every practicable weight, and were then many tons overweight; moreover, instead of over 29 knots attained by the *Bagley* and *Barney* and the 28½ knots attained by the *Biddle*, a speed of only a little over 26 knots was reached by the *Shubrick*, and with effort, while the *Stockton* was a little under 26 knots. The contract price for the boats built by the William R. Trigg Company was about $31,000 lower than those built by the Bath Iron Works, but it is believed that the actual money loss on each to the William R. Trigg Company is greater than that sum. The actual loss to the other contractors is not known to us, but their expenses have not yet ceased, as none of their boats has been accepted.

Considering the subject from the point of view of the execution of the work and the material results achieved or to be achieved, what has already been said indicates that it would be feasible, with sufficient knowledge and experience, to attain the results called for by the Department's circular, and, in fact, to exceed that on the torpedo boats. Whether it be possible to achieve the desired results on the destroyers has not yet been definitely ascertained. It is believed that all these destroyers (with possibly the exception of the *Stewart*) will be very much over their designed weight, which of itself will most probably prevent their reaching the contract speed. As indicating the probabilities in this line, it was stated to us that the Fore River Company had run some 24 trials on one of their destroyers, and had tried three successive sets of screw propellers, without coming anywhere near their contract speed of 30 knots; in fact, the highest speed attained so far had been about 26 knots. It may be added further that we were more favorably impressed by the general lightness and care in design of these Fore River vessels than of any other of the destroyers which were far enough along to be approaching completion.

This question of lightness and speed is one that may have its disadvantages, however. The vessels under construction by the Gas Engine and Power Company are very light, and it is stated that they are not at the present time seriously in excess of the

designed weights, but, as far as structural features are concerned, their lightness appears to be carried to the point of weakness, and everything has been sacrificed to obtain the required speed in smooth water. The destroyer *Stewart* is far from complete, however, and strengthening could readily be added to the hull at this time, but such additions might cause the contractor to fail to secure the speed required by his contract. This same contractor has finished and had accepted the torpedo boat *Bailey*. She exceeded her contract speed on trial, but the inadequate character of her hull and fittings has since been demonstrated.

Of all the destroyers, those giving the best evidence of strength are the three built by the Maryland Steel Company, the *Truxtun*, *Whipple* and *Worden*, which are on the contractor's own designs. Their original designed displacement on trial was to be 433 tons, but they will considerably exceed this weight. The scantling and construction of these boats are such as to make them thoroughly strong, and it is believed they are capable of going to sea in any weather, but the contractors are apparently not sanguine of obtaining the contract speed of 30 knots, and we are of the opinion that it is very doubtful whether they will attain the speed of 28 knots, the minimum allowed by the contract without rejection of the vessel. With reference to those vessels it may be said that as far as general service is concerned, in our judgment, they will be the best vessels in actual service of all those examined, provided no unexpected trouble in their machinery develop on trial.

Next in the results achieved may be placed the three destroyers built by the Neafie & Levy Company on the Department's plans, the *Bainbridge*, *Barry* and *Chauncy*. These vessels, while not so ruggedly constructed as the three just mentioned, are, it is believed, sufficiently strong to stand all ordinary, or, indeed, the severest weather, and it is thought that they do not so much exceed their designed displacement as the Maryland Steel Company's destroyers, although there will doubtless be an excess of over 30 tons in each vessel. The *Bainbridge* was at Newport at the time of our examination and was preparing for the official trial. It is somewhat doubtful if the contractors will on this trial

make the contract speed of 29 knots, as they have not yet succeeded in gettting more than about 27 knots on their own trials.

Next in order may be placed the *Dale* and *Decatur*, built by the William R. Trigg Company on the Department's design. The *Decatur* is now running preliminary trials in Chesapeake Bay, and we are consequently unable to examine her, but the *Dale*, which was at the works of the William R. Trigg Company, is stated to be identical in all respects. The results so far achieved on the trials of the *Decatur* were not stated by the contractors, but it is thought that they could not have been very favorable so far. These contractors are, however, in a somewhat better position than those for the other destroyers, as their contract calls for a speed of only 28 knots.

There remain of the destroyer class on this coast the *Hull* and the *Hopkins*, under contract with the Harlan & Hollingsworth Company. These contractors have not yet launched these two vessels, and they have entirely failed in getting a satisfactory trial on the torpedo boat *Stringham*, to which the destroyers have a general similarity. Under these conditions, we are of the opinion that the results to be expected from these boats when they are launched and tried will probably be very unsatisfactory, as it is understood that they are already overweight. These vessels are of the contractors' own design.

There remain three destroyers under contract with the Union Iron Works of the Department's design, the *Paul Jones*, *Perry* and *Preble;* these we have not seen. It is known, however, that the *Paul Jones* has had several trials and failed to attain the contract speed. There is, however, some chance that these vessels will reach their contract speed when the alterations to the sterns have been completed; this has been delayed by the strike at the Union Iron Works. These vessels are also overweight.

In conclusion, of the sixteen destroyers considered, it is probable that no one of them will be an entirely satisfactory vessel. The principal defects which exist are that in some cases their bows and sterns are insufficiently strengthened against wave action and vibration, and it is quite probable that their engines are not adequately balanced to run at high speeds. With these import-

ant exceptions, these vessels will be satisfactory, while possibly not of the very highest grade which could be produced by the most experienced designers and builders. It is, however, otherwise with the torpedo boats, except those built by the Bath Iron Works previously mentioned.

In achieving the results attained on the *Bagley*, *Barney* and *Biddle* every weight-saving device which the contractor was at liberty to use was resorted to, and among these was the extensive use of aluminum. It is believed that this will prove very unsatisfactory, and sufficient evidence of this is already visible on the *Dahlgren* and *Craven*, built by the same firm, which we visited at the Portsmouth Navy Yard. These aluminum parts, however, can be eventually replaced by steel, and probably will not make a very material difference in cruising speeds.

Of the remaining nine boats the only two thus far accepted are the *Stockton* and *Shubrick*, which are on the Department's designs, and the difference in the results attained by these two boats and by the *Bagley*, *Barney* and *Biddle* can be readily seen by the fact that these Trigg boats are 30 tons over-weight and attained three knots less speed than the vessels built by the Bath Iron Works.

The remaining torpedo boat under construction by the William R. Trigg Company is the *Thornton*, a sister ship of the other two, and she has as yet failed to get above 24.9 knots, and is about six tons more overweight than the other two, for causes which we are unable to ascertain.

The *Wilkes* is under construction at the works of the Gas Engine and Power Company. This vessel is quite far advanced, but has not yet had her trials. The construction used is generally light. It is reported that she is not greatly in excess of the designed weight so far. Some of the palpable defects on the *Bailey* have been remedied on the *Wilkes*, but considerable remains to be done to make the designs of details satisfactory. As the *Bailey* has achieved the very high speed required under the contract there seems to be some chance that the *Wilkes* will also fulfill her contract as to speed. This vessel is on the Department's designs.

The *Tingey* is building at the Columbian Iron Works, on the Department's designs. This vessel has not yet been tried. She is now in the water, the machinery is nearly ready to go aboard, the boilers are on board and the decks are being riveted up over the fire rooms. She is overweight, but just how much cannot now be stated, and whether she will achieve her contract speed is not yet known.

The *Blakely* and *De Long* were built at the works of George Lawly & Sons. They have been for some months past at Newport in an endeavor to make successful standardization trials, and it is understood that all efforts to reach a higher speed than 25 knots has been abandoned. The contract speed is 26 knots. These boats are on the Department's designs and are overweight.

There remain the *Nicholson* and *O'Brien*, building at the Crescent Shipyard. They are on the contractor's design, which differs from the Department's plans principally in the machinery and in a slight increase in the designed displacement. The peculiar type of boilers adopted by the contractor has led to a condition which is most unsatisfactory, in that the two forward boilers are fed from bunkers which are too narrow for even a small man to work in, and we do not see how it is possible to feed these boilers with coal from the bunkers at sea. These two boilers comprise two-thirds of the power of the boat. These boats have been out on a number of trials, and we understand have not yet attained a speed exceeding about 20 knots. The *O'Brien* came in from a trial trip while we were at the Crescent Shipyard, and although great reticence was exhibited as to the cause of what was an apparently unexpected return in the middle of the day, it is understood that it was due to the fact that the person in charge of the boat refused to run her at a higher speed than 20 knots, because the excessive vibration created at that speed was such as to make it altogether too risky to run the boat, the integrity of the main steam pipes being threatened.

With the exception of the boats built at Bath, these torpedo boats are deficient in stringers to resist vibration at the stern and the effect of waves on large flat surfaces at the bow, and to render them thoroughly seaworthy it is believed that at least one pant-

ing stringer should be run along at the bow and stern of these boats in general continuation of the stringer in the bunker at about mid-height.

It will be observed that we have dwelt on the increase of weights over those anticipated in the designs on almost all of these vessels. In torpedo boats this is a most important consideration, for at these high speeds a given increase of load, other things being equal, involves an increase in displacement of from five to ten times the amount of weight added. It is difficult, without prolonged examination, to state precisely where all these accumulated excess weights arise. Nor have we been able in our examination of these vessels to point where, without rebuilding them, it would be possible, at the present stage, to make material reduction in the weights carried. It therefore does not seem feasible, at the present time, to make any material modification in these boats which will lead to their success on trial. We have stated fully what, in our opinion, are the causes which have led to these conditions, and we believe that it will be essential to deal leniently with these contractors, if the Government does not wish to force them to the wall. As stated above, the destroyers will, when completed, be serviceable vessels. Some of the torpedo boats will be fairly good boats, but there are some of them which are likely to be flat failures.

We desire to emphasize further our opinion that the present contract trials of two hours' maximum speed with a very much reduced load from that carried in service does not adequately test the torpedo boats for the requirements of service. Paper results are not what are wanted in any well-considered system. It is desirable that the maximum capabilities of a boat in emergencies should be determined, and for this purpose a two-hours' trial seems to be the minimum length of time which will adequately determine the emergency power of the boat; but such trial should be under full load of requirement with two-thirds ammunition and stores and sufficient coal to carry the boat at ordinary steaming, say 1,000 miles, the coal consumption to be determined by a previous economy trial of twelve hours' dura-

tion at moderate speed, using only the evaporators to make up feed-water losses. In addition to this, where practicable, the boats should be given a run in heavy weather, such as frequently experienced on this coast, to determine their sea-worthiness and the suitability of their various fittings for such weather.

Very respectfully,

J. H. LINNARD, *Naval Constructor, U. S. Navy.*
L. H. CHANDLER, *Lieutenant, U. S. Navy.*

THE CHIEF OF BUREAU OF CONSTRUCTION AND REPAIR.

In reading the above report we find that special weight is put upon (1) the overweight of the boats, and (2) the excessive vibration due to lack of structural strength and lack of balance of the engines. Let us see how well these charges are borne out, so far as the machinery is concerned.

The total weight of machinery allowed for the Department-designed torpedo boats was 80 tons, or nearly 50 per cent. of the total displacement, 165 tons, of the boats. As actually built, the total weight of the machinery for the *Stockton*, *Shubrick* and *Thornton*, was approximately 86 tons, an excess of 6 tons, or $7\frac{1}{2}$ per cent. above the allowed weights. The total overweight of the heaviest of these boats was 36 tons, of which only $16\frac{2}{3}$ per cent. can be charged to the machinery, leaving $83\frac{1}{3}$ per cent. of the overweight to be charged against the hull and fittings. The same proportion holds for the two destroyers, *Decatur* and *Dale*.

Vibration due to lack of balance of the engines.—The destroyer *Decatur* has had her final trial since the above report was written, and, notwithstanding the unfavorable supposition made as to the probable results of the trial which was then in progress, she reeled off over 28 knots without the least difficulty. In speaking of the performances of her machinery the engineer member of the Trial Board reported as follows: "There was practically no vibration of the engines. The working of the engines at their highest speed indicated that they are well balanced, their framing is stiff, and their foundations are strongly built." A report to the same effect was also made by the full Board.

During the preliminary trials of the *Bainbridge*, which were

interrupted, unfortunately, by the failure of her fire-room blowers, it is also reported that the vibrations were very slight.

On the torpedo boats *Stockton*, *Shubrick*, *Thornton*, *Blakely* and *De Long* a careful analysis of the existing vibration shows that the greatest part of it is due to variation of torque, this variation tending to set up transverse vibrations of the engine cylinders. Unfortunately, in designing these vessels, in the desire to save weight, the engine foundations were lightened to such an extent, and the hull and framing in the wake of the engines were also made so light, that the requisite rigidity of the structure to withstand these transverse vibrations was destroyed. In order to restore this rigidity, the contractors found it necessary to fit transverse braces from the engine cylinders to the hull framing, and through these braces these vibrations are transmitted to the hull. Very probably a considerable decrease in the variation of torque and a corresponding decrease in vibration could be obtained by a readjustment and resetting of the main steam valves, increasing the work done by the L.P. cylinders and decreasing that done by the I.P.'s, this latter having been excessive as compared with the H.P. and the two L.P.'s.

It has been asked "why not try the Schlick-Tweedy system of balancing with these engines?" The best reply to this is to refer the inquirer to the German experiments on torpedo boat *S 42*, with four-cylinder triple-expansion engines, where, after setting the cranks according to the Schlick-Tweedy plan, it was found to have rendered the engines so uncertain in handling that it was not safe to allow *S 42* to cruise in squadron with other boats. The vibrations also, instead of having been decreased in amount, were found to be very much greater. In fact, the entire result of the change was so disappointing that the cranks were again placed and kept at right-angles, the H. and I.P. opposite, and the two L.'s opposite each other, this crank arrangement and the order of the cylinders being identical with that adopted for our own torpedo boats.

Let us now look at some of other boats. Two, the *Stringham* and *Goldsborough*, are built from foreign plans, and so far have proved to be decided failures. The *Dahlgren* and *Craven* are

also foreign designs, and, while doing very well on their trials, both fell nearly one-half knot below the contract requirements for speed. The *Bagley*, *Barney* and *Biddle*, have machinery practically identical in every respect with that of the *Dahlgren* and *Craven*. The contract as originally drawn allowed a machinery weight of 82.38 tons, almost exactly the machinery weight of the *Craven* as built. When completed, the machinery of these three boats weighed 91 tons, an excess of over ten per cent. It is stated that while building, the machinery weights allowed for these vessels was increased 10 tons, thus bringing them within the allowed weights when completed. If this same percentage increase of machinery weights had been allowed the Department-designed vessels, their machinery, instead of being a small percentage over weight, would have all been considerably under the allowed weights.

While the entire report is very discouraging in its general tone, yet if we compare it with the report on British destroyers, published in this same number of the JOURNAL, we can easily see that there is trouble in other houses than our own.

Request of Contractors building Torpedo Boats and Destroyers.—An extraordinary request has been made of the Navy Department by the contractors who are engaged on the work of constructing torpedo boats and torpedo-boat destroyers. Most of the ships authorized three years ago for completion within twelve and eighteen months are still uncompleted. There have been repeated applications for extension of time, usually on the ground that there was difficulty in obtaining material which enters into the composition of these small ships. These requests have been granted by the Navy Department, and applications have now been made by the contractors that the Government increase the contract price for which the builders agreed to construct the boats. It is requested that 40 per cent. of the contract price be added to the amount originally named. This request is based on the assertion that the contractors have found the work of construction much more costly than they imagined, and in nearly all the cases the contractors have lost an appreciable sum on the

work. This is by no means surprising; in fact, at the time the bids were presented the amounts named in the proposals were regarded as exceedingly low, and the Navy Department authorities informed the contractors that they probably would make nothing on their contracts taken at such figures. A number of the firms were entirely inexperienced in the work and evidently desired the contracts as a means of advertising or developing their plants. Whatever may have been the object in bidding for contracts at ruinously low figures, there have been disastrous results. In two instances the contractors have been practically ruined.

Of course, the Navy Department has no authority to increase the contract price in any instance, and the matter will have to go to Congress, but it will be an assistance to the efforts of the contractors if the Navy Department indorses the application of the contractors. That question is now in abeyance. The Secretary of the Navy has called for a report on the subject from the Board on Construction, among the members of which there is a difference of opinion as to the justice of the request. Some of the members believe that an allowance of 40 per cent., or any addition to the contract price, will establish a dangerous precedent, and that contractors who name sums for certain work should suffer the loss, if there be any.—"A. & N. Register."

Torpedo Tubes.—The Navy Department has decided not to place torpedo tubes on the new battleships and armored cruisers. This action marks the abandonment of the torpedo as an implement of warfare to be carried by our largest ships of war.

Bainbridge.—This torpedo-boat destroyer attempted to run off her contract trial on December 17, but was forced to abandon it on account of the failure of her forced-draft blowers.

Battleships and Cruisers, new.—The plans for the new battleships and armored cruisers, formulated by the Naval Board on Construction, call for vessels of the following dimensions: For the cruisers, length on load-water line, 502 feet; beam, 78 feet 8½ inches; trial displacement, about 14,500 tons; maximum displacement at full load, about 15,960 tons; maximum draught, about 27 feet 2 inches; total coal capacity, about 2,000 tons;

indicated horsepower, 25,000; trial speed, not less than 22 knots. The armament will consist of four 10-inch rifles, sixteen 6-inch, twenty-two 3-inch, twelve 3-pounders and fourteen smaller guns. The water-line-belt armor would be 7½ feet wide, with a maximum thickness of 6 inches, tapering to 3 inches at the ends. The barbettes for the 10-inch-gun turrets would be from 7 to 4 inches thick; the turrets for the 10-inch guns would be 8 inches thick with 9-inch port plates. The conning tower and its shield would be 9 inches thick. Each vessel would carry 854 officers and men.

The plans for the new battleships, as fixed by this Board, make these vessels 450 feet long, 76 feet 8 inches beam, 26 feet 9 inches maximum draught, 17,604 tons maximum displacement. They would carry 2,200 tons of coal, have 16,500 I.H.P., and a trial speed of not less than 18 knots.

The battery will consist of four 12-inch guns, eight 8-inch, twelve 7-inch, twenty 3-inch, twelve 3-pounders, and eighteen smaller guns. The armor belt would be 3 feet 3 inches wide, and be 11 inches thick, tapering to 4 inches at the stem and stern. The 12-inch barbettes would be 10 inches thick, with turrets 9 inches thick, and 11-inch port plates. The crew would include 797 officers and men. The Board decides against sheathing, admitting that while this sheathing and coppering are partial protections against fouling, there are decided disadvantages in sheathing, and that under ordinary conditions the bottoms of these ships can be kept sufficiently clean by the use of anti-corrosive and anti-fouling paints. The Board approves of the elliptical balanced turret, with inclined port plates, as the best form. Torpedo tubes on heavy armored vessels not recommended, the Board believing that torpedo warfare should be left to torpedo boats and to smaller cruisers. The 7-inch gun proposed does not yet exist in our Navy in an acceptable and tried form, but can soon be provided. —"Engineering News."

Florida.—The monitor *Florida* was launched November 30, from the Crescent Ship Yard, Elizabethport, N. J. The launch was in every way a success. All the armor and machinery and boilers were placed in the vessel before the launch.

Her dimensions are as follows :—

Length, feet	252
Beam, feet	50
Mean draught, feet and inches	12–6
Displacement, tons	3,235
Speed, knots	11.5
I.H.P.	2,400
Engines, triple expansion	2
Cylinders, inches	17, 26½, 40
Stroke, inches	24
Revolutions	200
Boilers, Normand	4
Heating surface, square feet	9,504
Grate surface, square feet	240
Steam pressure, pounds	250

The sides are protected by continuous belts of armor 5½ inches thick below the water line and increasing to 12 inches at the water line. The armament consists of two 12-inch guns, placed in single turret, with 12-inch armor mounted en barbette, forward. There are four 4-inch rifles and a secondary battery of ten small guns.

Fulton.—It is evident that the Holland Torpedo-Boat Company will leave nothing undone to meet every possible requirement of the Government in the matter of their submarine torpedo boats. To this end one of these craft, the *Fulton*, was hermetically sealed with a crew and officers inside and submerged for 15 hours on November 24–25. No inconvenience was experienced by those who took part in the trial.

Kentucky.—In one of the late numbers of London "Engineering" we find a report of an interesting trial run of the British cruiser *Terrible*, in which it is noted that after being several years in commission she has repeated her first official trial performance.

Since the publication of this item a report from the U. S. battleship *Kentucky* has been received, giving the details of a two hours' assisted-draft trial and a twelve hours' trial—ten hours natural and two hours assisted draft—made by that vessel on December 3, 1901, while making passage from Hong Kong to Amoy, China.

The conditions under which the *Kentucky's* trials were run were as follows:

The trial began at noon, on December 3, with the main engines running about 80 revolutions and with all the usual auxiliaries, including ice machine and two evaporators in use.

At 4·00 P. M. a section and the odd numbers of the following section came on watch, got out coal and prepared for assisted-draft run of two hours. The ice machine and evaporators were shut down.

The forced-draft blowers were started and fire-room air-tight doors closed at 4·35. The ship was steaming into a long swell, causing the engines to race slightly. Everything in engine and fire rooms was working perfectly, but did not increase air pressure on account of the racing of the engines. Finished first two hours with half the engineer's force on duty at 6·35. The forced-draft blowers were slowed and the fire rooms opened to get out ashes. The watch on duty was relieved by the other half of the engineer's force, blowers started and airtight doors closed at 7·15 for the second period of the assisted-draft trial. Engines were racing slightly on account of a long swell ahead, otherwise the engines, boilers and auxiliaries were working perfectly.

The main-engine throttles were wide open within the first five minutes with 178 pounds of steam at the engines and the cut-offs were opened out twice during the period, so that during the last half hour they were nearly "full" open. The pitching of the ship, diving into the seas, with the draught of the ship about 22 inches deeper than on builder's trial and being about 5 inches down by the head, will account for not making more revolutions. There was not the slightest heating of main engines or auxiliaries, no appreciable leaks about boilers or piping, and the safety valves did not lift.

The sea was getting up before the end of the second period (9·15), and at times the forecastle was covered with 6 to 8 feet of water, and sheets of spray were going over the top of the pilot house, 43 feet above the water line.

A synopsis of the greatest power for two hours, and also a synopsis of the log for twelve hours, from noon until midnight,

placed in parallel with the data of the *Terrible's* performance, follows:

.....	*Kentucky.*		*Terrible.*	
Duration of trial, hours	2	12	4	20
Speed in knots and tenths	16	13.2	21	18.5
Force of wind	3 to 4	3½	2	2 to 4
Direction and kind of sea	Ahead, rough.	Ahead, long swell.	Smooth.	Smooth.
Revolutions per minute	104.55	91.45	106.5	94
Steam pressure in boilers, in pounds per square inch, above the atmosphere	173	161.8	230	230
Steam pressure at engines, in pounds per square inch, above the atmosphere	169	156.8	200	200
Steam pressure in receivers, in pounds per square inch, above a perfect vacuum:				
First receiver	78.2	59.65	...	...
Second receiver	25.9	21	...	...
Steam cut off from the beginning of the stroke, in decimals of the stroke:				
H.P. cylinder	.665	.656	.70	...
I.P. cylinder	.665	.658	...	...
L.P. cylinder	.705	.6775	...	...
Opening of the throttle, in tenths	Wide.	.21	...	...
Vacuum in condenser, in inches of mercury	25.55	25.1	25	25
Temperature in engine room, degrees F	90	96	...	...
fire room, degrees F	125	123	...	...
of injection water, degrees F	67	69.5	...	...
discharge water, degrees F	128	148	...	...
feed water, degrees F	155	162	...	...
Draught of vessel, measured at the time, feet and inches:				
Forward	25-7	25-7	27-5	27-5
Aft	25-1	25-1	29-10	29-10
Air pressure, in inches of water	.34	...	...	...
Revolutions of air pump	25	20	...	...
circulating pump	100	99	...	...
I.H.P. of air pump	8	8	...	...
circulating pump	7	7	...	...
H.P. cylinder	1,560.65	1,067.9	...	...
I.P. cylinder	1,526 00	872.05	...	...
L.P. cylinder	1,867.35	1,052.9	...	...
aggregate	4,954	2,992.85	...	...
Estimated H.P. of all other auxiliary machinery in operation	220	195	...	...
Collective I.H.P.:				
All main engines	9,908	5,985.70	24,693	15,129
Air and circulating pump	30	30	...	...
All other auxiliary machinery	220	195	...	...
Total	10,158	6,210.70	...	...
Pounds of Cardiff (Welsh) coal, net weight, consumed per hour	19,950	12,687 5	...	...
I.H.P. per square foot of heating surface	.451	.281	...	...
Pounds of Cardiff (Welsh) coal, net weight, per I.H.P. per hour for all machinery in use	1.96	2 04	2.3	2.16
Number of square feet of grate surface in use	684.8	684.8	...	...
heating surface in use	22,103.8	22,103.8	...	...
Pounds of coal per hour per square foot of grate surface	29.1	18.52	...	...
(Two evaporators and the ice machine in operation on *Kentucky* while not under forced draft.)				
Condition of bottom	Clean.	Clean.	Slightly foul.	
Distance run per ton of coal, knots	1.8	2.3	...	...
Pounds of coal consumed per knot	1,247	961	...	...

The *Terrible* also claims a coal expenditure per horsepower of main engines of only 2.19 pounds for forced draft and 1.9 pounds

natural draft. Allowing these amounts to be correct, we find that the amount of coal per day consumed for the auxiliaries alone is in the first case about 30 tons and in the second case about 42 tons. This great increase of expenditure for auxiliaries at the lower power over that required at the higher appears very queer and seems to require an explanation. As it stands, however, with the explanation lacking, the data for coal consumption for the main engines cannot be regarded as reliable.

However this may be, the showing made by the *Kentucky* while developing very nearly her contract-trial power, and also while under natural draft, is far better, so far as coal economy of the machinery, than that made by the *Terrible*.

The Launch of the Battleship Missouri.—The battleship *Missouri*, which was launched at the Newport News Shipbuilding and Dry Dock Company's yards on December 28, 1901, is the last of the three fine battleships of the *Maine* class to take the water. The *Maine* was launched at the Cramps shipbuilding yards, Philadelphia, Pa., May 30 of last year, and the *Ohio* was launched on May 22 at the yards of the Union Iron Works, San Francisco, Cal.

The *Missouri* is an enlarged *Alabama*, with all the excellent characteristics of that ship and the added advantages of higher speed, larger coal capacity and a more powerful battery. To secure the necessary 16,000 horsepower for 18 knots speed, the *Missouri* is equipped with twelve Thornycroft water-tube boilers and twin-screw, vertical, triple-expansion engines with cylinders 34¾ inches, 53 inches, (two) 63 inches, and 48-inch stroke. The heating surface of the boilers is 51,372 square feet and the grate surface 1,000 square feet. The steam pressure at the engines will be 250 pounds. Her length is 388 feet; beam, 72 feet 2½ inches; mean draft, 23 feet 6 inches. The displacement given, 12,230 tons, is that of the vessel when she is fully equipped, ready for sea, with all stores on board and a normal coal supply of 1,000 tons. When loaded to her fullest capacity she will displace 13,500 tons.

There is an armor belt extending from the stem more than two-thirds of the way aft, which has a maximum thickness of 11

inches at the top and 7½ inches at the bottom, this thickness being maintained in the wake of the engines and boiler room. From the forward barbette the belt tapers to a thickness of 4 inches at the stem. Above the main belt there is a complete wall of 6-inch armor, which covers the sides of the vessel between the main barbettes and extends to the level of the spar deck. Diagonal bulkheads of heavy armor extend from the main belt to a junction with the barbettes, while above the main bulkheads are bulkheads of 6-inch armor reaching from the 6-inch side armor to the main barbettes. The protection thus afforded against an enemy's projectiles is supplemented by the coal bunkers, which extend in the wake of the 11-inch and 6-inch side armor, and present a thickness of from 6 to 10 feet of coal against penetration by projectiles which might effect an entrance through the Krupp armor. Further protection against the entrance of water is afforded by a belt of cellulose, 3 feet in width, which is worked in at the back of the 6-inch armor at the point of its junction with the main 11-inch belt. The main barbettes for the 12-inch guns are protected with 12 inches of Krupp armor, while the turrets are 11 inches in thickness, except on the port plates, where the armor is increased to 12 inches.

The main battery of four 12-inch guns is carried in the two main turrets forward and aft. The secondary battery consists of sixteen 6-inch rapid-fire guns. Of these, ten are mounted on the main deck behind the 6-inch armor, each gun position being separated from the next by a screen of 2-inch armor. Forward, toward the bow on the same deck, are two separate gun positions, protected by 6 inches of Krupp armor, in which are mounted two more of the 6-inch battery, while the other four 6-inch guns are carried two on each side of the vessel upon the spar deck, the protection consisting of 6 inches of steel. The rest of the rapid-fire battery consists of six 3-inch guns, four of them mounted on the gun deck aft and two of them on the main deck forward; eight 6-pounders and two 1-pounders mounted on the bridges and fighting tops, besides two Colts and two 3-inch field guns.

A new feature, which has not before been adopted in the

United States Navy, is the submerged torpedo tube, of which the *Missouri* will carry two. The torpedo tubes on the *Missouri* are located well below the water line, and the firing stations for these tubes, which are above the water line, are well protected by armor.

Although the *Missouri* has substituted the lighter 12-inch gun in her main battery in place of the 13-inch gun carried by the *Alabama*, she will be able to deliver a much more powerful fire from these guns alone. Moreover, she carries two more guns of 6-inch caliber, and several of the very effective 3-inch pieces. All of these weapons are of the new long-caliber, smokeless-powder type, the 12-inch guns being 40 calibers in length and the 6-inch and 3-inch 50 calibers in length. The 12-inch gun has a muzzle velocity of 2,800 foot-seconds, and a muzzle energy of 46,246 foot-tons; the 6-inch piece has a muzzle velocity of 29,000 feet per second and a muzzle energy of 5,838 foot-tons; while the 3-inch gun has a muzzle velocity of 2,800 feet per second and a muzzle energy of 709 foot-tons. At 3,000 yards the 12-inch projectile, if provided with a soft cap, can penetrate 19.5 inches of Krupp steel, while the 6-inch projectile, if capped, can penetrate 5.9 inches of steel. The *Missouri* will have a complement of 551 officers and men.—"Scientific American."

The Submarine boat Plunger, built at the Crescent Shipyards at Elizabethport, N. J., was successfully launched on February 1. The *Plunger* is a sister ship of the *Adder*, the *Moccasin*, the *Porpoise*, the *Shark* and the *Fulton*, which were built by Mr. Nixon and will shortly be placed in commission. The vessel will have a speed on the surface of about eight knots, and a radius of action of about five hundred miles. The submerged speed will be about seven knots, with a radius of about forty miles. She will carry a crew of seven men when equipped and ready for service. The armament will consist of one torpedo tube, and the vessel will carry three of the new long Whitehead torpedoes.

Submarines.—The Board of Construction of the Navy Department decided at one of its late meetings that all the new submarine boats should fulfill the requirements of the contract and that no single boat should be taken as a type and tried for the

entire number. The decision was based on a request from the builders of the *Fulton*, which has recently undergone some submerging tests. They wished to use the *Fulton* for an acceptance test of the other boats. The construction board held that as Congress authorized these vessels against the recommendations of the naval officials and stipulated in the act what requirements should be met, the Navy Department is bound to insist that the law be strictly carried out. The Board meeting did not develop any change in the opposition of members to providing this type of war craft and the opinion was generally expressed that the boats were in an experimental stage, and could not be authorized for the Navy until their value had been amply demonstrated.

Thornton.—This torpedo boat, after running off successfully her standardization trials on December 16, attempted to make the two hours' contract trial on the afternoon of the 17th.

After running for 35 minutes the discharge pipe from the port air pump carried away, making it necessary to stop the trial until repairs could be made.

On the following day, temporary repairs having been made, another attempt to run off the trial was made. After running for 70 minutes at a mean speed of 26.33 knots per hour, the trial was abandoned on account of a small steam pipe supplying steam to the evaporator pump, carrying away in the after fire room, the steam rendering the fire room uninhabitable.

The New United States Warships.—No warships, perhaps, have had so many vicissitudes as the United States battleships of the *New Jersey* (?) class. Once again they have been definitely decided on, permanently, perhaps, now; but it need not be forgotten that earlier designs have been "final" also. There is no getting away, however, from the fact that each new finality has been better than preceding designs. As with each the displacement has gone up, this is not to be wondered at; but the great and essential point is this increase of displacement. In the past American ideals have tended to "whip creation" with the minimum of displacement; now obviously nautical influences can be seen at work, with the result that we observe an honest striving after a real best in place of what, rightly or wrongly, has hitherto been

under suspicion of being rather a paper best. In fine, America is now definitely settling to building American warships to American needs.

The new battleships are to be of 17,604 tons normal displacement, 450 feet long, by 76⅔ feet beam, by 26¾ feet minimum normal draught—the relatively small draught being necessitated by the depth of water about the American coast. Our 16,500-ton *King Edward* class will be, therefore, small ships beside them. The main belt, 9¼ feet deep, will be 11 inches thick on the water line amidships, this thickness soon fading to 9 inches, and diminishing to 4 inches at the extremities. Here, then, we have the maximum of moderation in the disposal of the 4,000 to 4,500 tons odd of armor. No weights have yet been published, but, very approximately, this belt can be put at about 1,500 to 2,000 tons odd. A 7-inch belt protects the lower deck above—roughly, another thousand tons nearly. This, of course, includes bulkheads. The balance of the armor goes to barbettes, turrets and battery. The armament will be four 12-inch guns in the usual turrets, eight 8-inch at the angles of the superstructure—the somewhat amateurish superposed turret idea being discarded—and ten or twelve 7-inch guns in the battery, protected by 7-inch armor. This 7-inch gun is a piece yet to be built. It is to be adopted because it "will pierce 7 inches of armor at 3,000 yards." At sea, in battle, it is not likely to do anything of the sort, and the carrying of A. P. projectiles for the purpose must lessen the supply of the more useful, common and high-explosive shell. However, no constructors have yet grasped the idea that secondary guns are shell guns, and that with high explosives to burst outside near a gun muzzle is likely to be more destructive than to make a hole in the place where the gun is. The great thing is to disable the gun. The burst of a 7-inch shell will be far superior to that of a 6-inch, but the latter is, with H. E., powerful enough for anything against so ideal a target as a ship. The Americans, would, we think, have been wiser to have had the same weight in 6-inch pieces, unless, as is possible, space for them and their ammunition arrangements constitute the objection.

A remarkable feature of the new ships is the absence of all

torpedo armament. This, too, we consider a mistake. After all, the weight of submerged tubes is a bagatelle in 17,604 tons; nor, in so large a ship can the saving of space matter very much. Useless the torpedo may be for long-range actions, but it has had much to do with the new leaning to long-range work. After many guns are disabled, after speed is reduced, ships are likely to get within torpedo range, while the absence of tubes is a draw to the enemy to do so. To be sure, by then all directors may be smashed; but of this there is no certainty, while the same objection might be extended to sighting hoods for guns and many other things.

We have drawn attention to these defects, not in a carping spirit, but because in spite of them we still hold these 17-604-ton ships so far as the meager details available allow, superior to any other battleship designs, not merely as ships, but per ton of displacement. Political events, too, add an interest to American sea power. We are small believers in the Utopian dream of a great Anglo-Saxon world empire; but there are many indications that, whether the idea be pleasant to Americans or not, the great war of the future will find their ships fighting side by side with ours.

The new cruisers are, as yet, so shadowy that it is impossible to criticise them to any extent. But nothing could be sounder than the principle laid down by the Board, that while a battleship may have 22 to 28 per cent. of armor, cruisers must be content with from 7 to 20 per cent., the balance being expended in speed. It is a palpable truth enough; but a review of existing types would hardly go to prove it conclusively. The nations are realizing it slowly.

The armament spoken of for those vessels is four 10-inch and sixteen 6-inch, no great change over existing models, save in the adoption of 10-inch in the place of 8-inch for the turret guns. The horsepower is 25,000 with 22 knots. For the battleships, speed has been written down as a minor desideratum, and they will be 18 knots only, with 16,500 horsepower.

A very important feature in both types is the abolition of

triple screws, after which the engineer-in-chief is supposed to hanker. Executive officers seem to have formed the opposition, and they have carried the day on the grounds that however advantageous the triple system may be in coal economy, it lacks the tactical advantage of the twin-screw system. Purely engineering disadvantages might also be alleged, but the primary question is one of fighting capacity. With two screws there is over 8,000 indicated horsepower available for assistance in a sudden turn; with triple screws considerably less power is available. This is the gist of the argument that has carried the day again with the United States Construction Board, and it argues a sound appreciation of a warship as a fighting machine before all else. This is the dominant note all through the report, from the specific reasons against wood sheathing—of which we shall have more to say on another occasion—the situation of magazines and facility of ammunition supply. Never before do we remember to have seen American designs thought out with so single an eye to the practical in all things. One may well contrast these new battleships with the *Iowa*, of 6,000 tons less displacement. The *Iowa* has almost as much weight of armor, while in armament the chief difference is ten 7-inch instead of six 4-inch, a small matter of weight in 6,000 tons. The new-type ship will carry 2,000 tons of coal normally, an increase of 1,375 tons over the *Iowa*, and her horsepower, and consequently the weight of machinery, is increased. Still the 6,000 tons is not to be made up with these things alone, and there is indubitably a heavy balance expended in strength, in solid necessaries, that do not show on paper.—The "London Engineer."

ARGENTINE.

General Mitra and General Roca.—The Argentine Government has ordered two more *Garibaldis* in Italy. The new ships will be 8,500 tons, against the 7,000 tons odd of the *Belgrano* and *Pueyrredon*, the last they had of the type; 17,000 indicated horsepower and 21 knots against 13,000 indicated horsepower and 20 knots. The names selected are *General Roca* and *General Mitra*.

AUSTRIA.

Battleships, new.—The Austrian naval authorities have decided to adopt Yarrow water-tube boilers in the three battleships about to be laid down of 11,000 tons and 14,000 horsepower.

Battleships and Cruisers, new.—The Austrian Navy is to be greatly strengthened during the next two years. There are now on the stocks three battleships, one of 11,000 and two of 10,000 tons, with a speed of 18 knots for the first and of 19 for the others. To these are to be added a division of new cruisers of 7,480 tons with a speed of 21 knots, and two river monitors for the Danube.

ENGLAND.

Arrogant.—As an experiment the six after boilers of the British cruiser *Arrogant* are to be fitted to burn liquid fuel.

Bacchante.—The Clydebank-built cruiser H.M.S. *Bacchante*, has successfully completed her series of steam trials. The first was for thirty hours at 4,500 indicated horsepower, when the following results were obtained: Mean indicated horsepower, 4,624 with 75.2 revolutions per minute, corresponding to a mean speed of 14 knots. The coal consumption per indicated horsepower per hour was 1.8 pounds. The second trial was for thirty hours at 16,000 indicated horsepower, and the actual average indicated horsepower recorded was 16,445, with 112.7 revolutions per minute, and a mean speed of 20.6 knots per hour. The coal consumption per indicated horsepower per hour was 1.75 pounds. On eight hours' full-power trial on the 7th inst., the mean results recorded were 21,520 indicated horsepower with 120.1 revolutions per minute, and 1.7 pounds of coal per indicated horsepower per hour, the very high speed of 21.75 knots being maintained as the average of the eight hours' running. Her principal dimensions are: Length, 440 feet by 69 feet 7 inches beam, and at her load draught of 26 feet 3 inches, to which she was brought, she has a displacement of 12,050 tons. She is designed specially for service on foreign stations, and with her great speed and powerful armament should be a most valuable addition to His Majesty's Navy.

Battleship, new.—The Devonport dockyard authorities have received instructions to prepare for building a battleship larger than any now existing. Its displacement will be 16,500 tons, and its length 425 feet. The previous largest battleships, designed for the British Navy are of the *Queen* class, with a displacement of 15,000 tons, and a length of 400 feet.

Cruiser, new.—The new cruiser which is to be laid down in the Pembroke dockyard has not yet been named, but by many it is expected she will be called the *York*. *Pembroke* is another name suggested. The new vessel will be ten feet longer than the *Essex* and one foot wider, and she will be fitted with Babcock & Wilcox boilers. It has been decided that the *Drake* and *Essex* shall be ventilated by the system recently proposed to be introduced on the *Pactolus*, *Prometheus*, *Pelorus*, *Majestic*, *Hannibal* and other ships. The two cruisers were originally to have been fitted with cowls, but, as they are to steam at 23 knots, it was thought better that they should be fitted with electric fans instead, with a view to minimizing the resistance.

Cruiser, new.—The plans for the new cruiser not yet named, but which, according to the building program, should be laid down during this financial year, have been issued. Her length will be 425 feet between perpendiculars, with 10,000 tons displacement, and propelling machinery of 22,000 horsepower. A sum of £33,476 is proposed to be spent on this vessel up to April next. Of this amount £3,000 is for labor, and the remainder for contract work, materials, torpedo tubes, &c. The boilers, engines and machinery will be supplied by contract. A large quantity of the material has arrived at the yard, but none of it has yet been prepared, as the drawings are yet in the draughtsmen's hands (see following)—"Naval and Military Record."

New Cruisers.—The specifications for the five new first-class armored cruisers for the Navy have now reached the builders. An interesting feature is that the vessels will be fitted with large-tube Yarrow boilers. The cruisers will be of 9,800 tons displacement, and will have a speed of 23 knots. A sixth cruiser of the class will be built at Chatham.—"Naval and Military Record."

Drake.—The steam trials of the machinery of the *Drake*, as far as they have proceeded, are considered to have been exceptionally satisfactory. The water tests were completed, without a hitch, in a couple of days. The steam-pressure tests of the safety valves, which had to be conducted singly, occupied a fortnight, and the accumulation trials two days. During the latter trials it was found possible to burn in each boiler 875 pounds of coal—the amount officially stipulated—in about twenty minutes, during which period the steam generated was exhausted through the safety valves without exceeding at any time the stipulated pressure of 300 pounds to the square inch, at which it is required to leave the boilers when the engines are working. This confirms the pressure tests of the safety valves, and proves that they afford a sufficient outlet for all the steam formed, even under extreme conditions when the engines are not working. If the area of the safety valves had been too small to discharge the steam as rapidly as it was generated at 300 pounds to the square inch, a greater pressure would have been developed. The specifications required that half the coal used for the purpose of these trials should be placed in the furnaces before they were lighted, the remainder being thrown in, one half at a time, as combustion rendered necessary.

At the outset of the steam trial of the propelling engines the reversing engine on one side gave a little trouble. The main engines however, on both sides started as soon as steam was admitted to the cylinders, and worked splendidly, both going ahead and astern. The remarkable absence of noise and vibrations was much commented upon. These engines, which are unitedly of 30,000 horsepower, are the most powerful ever fitted in a ship at any Royal dockyard. Their cost, with that of the auxiliary machinery, will be £276,178, including £10,571 for machinery not mentioned in the original specification.—"Naval and Military Record."

Fantome.—The *Fantome*, sloop, returned to Sheerness on the 8th instant from a thirty hours' steam trial to ascertain her coal consumption. The trial proved satisfactory in every respect. The run was ordered to be made at 300 horsepower, and the en-

gines indicated 339 horsepower, with a mean coal consumption of 1.71 pounds per indicated horsepower per hour, and an average speed of 9¼ knots per hour.

These trials were specially interesting, as they were conducted under the direction of the Water-Tube Boiler Committee—this vessel being the first to be fitted with the Niclausse boiler since it was experimentally tried in a torpedo-gunboat of the *Sharpshooter* class. On the low-power run the mean result was 339 indicated horsepower, with a coal consumption of 1.710 pounds; while the sister ship *Espiegle*, with Babcock & Wilcox boilers, at 337 indicated horsepower, consumed only 1.53 pounds; two Belleville-boiler ships, *Mutine* and *Rinaldo*, at the same power, burning 1.86 pounds and 1.90 pounds respectively. On the second thirty hours' trial at 75 per cent. of the full power, the Niclausse-boiler ship, at 1,020 indicated horsepower, equalled that with the Babcock boilers, the rates being respectively 1.53 pounds and 1.54 pounds; while the Belleville ships named returned 1.72 pounds and 1.60 pounds. On the full power the Niclausse-boiler ship did well again. Her power was 1,453 indicated horsepower; speed, 13.63 knots; and coal consumption, 1.53 pounds. The *Espiegle*, with the Babcock & Wilcox boilers, consumed 1.70 pounds, and the two Belleville-boiler vessels 1.63 pounds and 1.61 pounds respectively.

Fast Cutter.—Messrs. Simpson, Strickland & Co., Limited, Darthmouth, Devon, have recently built and engined a 30-foot steam cutter, which has made some remarkable performances. At a recent trial before Admiralty officials, the vessel reached a mean speed during four runs—two with and two against the tide—of 18.35 knots, according to the Admiralty timekeepers. The maximum speed during the trials was 20.05 knots per hour, which is a remarkable performance, and we believe is the fastest speed ever attained by a vessel of this size. The builders claim that this performance is practically the same as that attained by the turbine-propelled vessel *Turbinia*. Some alterations have been made on the propeller since the trials mentioned, and these have resulted in a mean speed of 18.75 knots with and against the tide. The following are the dimensions of the vessel:

Length, over all, 30 feet; beam, 6 feet 3 inches; mean draught, 18 inches; displacement with steam up, 2 tons 10 cwts.; Admiralty co-efficient of hull, 110. She accommodates six passengers. The vessel is fitted with Cross patent four-crank quadruple engines; cylinders, 3¾, 5, 7½ and 11 inches diameter; stroke, 4½ inches; weight, 8 cwts. 2 qr. 17 lbs.; steam pressure, 350 pounds; 1,200 revolutions; indicated horsepower, 140. The boiler is of the Thornycroft-Cross patent water-tube type. Nickel-steel has been largely used in the engines and boiler. The total weight of machinery is about 25 pounds per indicated horsepower. There was exceedingly little vibration at full speed, and the trial runs were highly satisfactory.

Fearless.—This vessel had to run three trials before she was pronounced satisfactory. On the first everything went satisfactorily until within ten minutes of completion, when hot bearings led to the abandonment of the trial. The *Fearless* proceeded to sea again two days later, but she encountered thick weather, rendering it unsafe to continue the trial, and she had to return to the harbor. On the next day, at the third attempt, she was successful, the results being very satisfactory. The Navy list gives the natural-draft horsepower of the *Fearless* as 2,100, but the mean for the last run was 2,187 horsepower, which is 87 in excess of the official figure, and some 40 horsepower better than was obtained after the *Fearless* was repaired a few months since. The *Fearless* averaged a speed of 14.5 knots per hour. These results were attained with a mean pressure of 117 pounds of steam in the boilers, and the engines averaging 132.55 revolutions per minute.

Hogue.—The trials of the *Hogue* were carried out in an exceptionally short period, not the slightest hitch interfering with the program originally drawn up by the Admiralty, and she experienced sufficiently rough weather to establish her steadiness as a gun platform under adverse conditions. On the full-power trial the mean speed of four runs between the Lizard and Dodmans Point was 22.06 knots, the speed on the four runs being respectively 21.8 knots, 22.2 knots, 21.5 knots, and 22.75 knots, while the designed speed was only 21 knots. The maxi-

mum power was 22,154 indicated horsepower, and the mean on the four runs, 21,432, while the contract called for 21,000 indicated horsepower. The results, therefore, are eminently satisfactory. On the trial of thirty hours' duration at what is termed the continuous-steaming power—that at which the vessel must go as long as her coal lasts—the speed was 20.15 knots for 16,456 indicated horsepower; while at one-fifth power—the ordinary cruising condition—the speed was 13 knots for 4,738 indicated horsepower. We tabulate the full results of all three trials:

TRIALS OF H. M. S. "HOGUE."

.....		Thirty hours' coal consumption, December 11 and 12.		Thirty hours' coal consumption, December 13 and 14.		Eight hours' full power, December 17.	
		Starboard.	Port.	Starboard.	Port.	Starboard.	Port.
Mean steam in boilers		190	190	...	...	285	285
at engines		179	179	220	226	221	221
air pressure in stokeholds		...	...	...	...	.4	.4
cut-off in H.P. cylinder, per ct.		30	30	...	...	78.7	78.7
vacuum		27.3	26.8	25.6	25.5	25.1	25
revolutions		74.8	74.6	113.1	111.6	123.6	121.4
Mean pressure in cylinders...	High	41.8	44.5	102.5	104.3	116.6	112.1
	Intermediate	15	15	34.7	34.8	38.4	39.7
	Low, forward	6.2	6.5	13.3	13.8	18.6	18.8
	aft	6	6.2	13.5	15.3	19.3	20.3
I.H.P.	High	773	820	2861	2874	3405	3358
	Intermediate	748	745	2604	2580	3144	3198
	Low, forward	412	428	1326	1361	2028	2016
	aft	398	414	1348	1502	2109	2174
Total I.H.P.		2331	2407	8139	8317	10686	10646
Gross total I.H.P.		4738		16456		21432	
Mean speed		13 knots.		20.15 knots.		22.06 knots.	
Coal		2.09 lbs.		2.05 lbs.		2.06 lbs.	

The trials, it should be stated, were carried out with a close approximation to service conditions. The coal was not hand-picked, nor were the stokers specially-trained men. The *Hogue* is an armored cruiser of 12,000 tons displacement at 26 feet 3

inches draught, her length being 440 feet, and her beam 69 feet 6 inches. She has 6-inch armor on her broadside, and her armament includes two 9.2-inch breechloading guns, with twelve 6-inch quick-firers and 17 smaller weapons. The Vickers mountings for 9.2-inch guns have in their trials enabled five rounds (380 pounds), per minute to be fired. The machinery of the *Hogue* is of the twin-screw triple-expansion type, each set having four cylinders, respectively 36 inches, 59 inches, and two at 68 inches in diameter, all having a stroke of 48 inches. The thirty water-tube boilers have an aggregate grate area of 1,650 square feet, and a heating surface of 51,500 square feet, and on trial the power was equal to practically 12 indicated horsepower per ton of machinery.—" Engineering."

Hyacinth and Minerva.—Another series of competitive trials between the above-named ships has been sanctioned by the Admiralty. It is understood that their propellers will be removed and the engines worked at the lowest power to the highest, to ascertain their friction. The propellers will then be replaced and the cruisers in company be tested over a 28-mile course at various speeds.

Irresistible.—Since the return of the *Irresistible* from her steam and gunnery trials workmen have been engaged in overhauling the machinery and gun fittings. These have been found satisfactory, and have been accepted from the contractors and passed into the hands of the dockyard authorities. The ship, however, shows a structural defect of the upper deck as the result of the firing of her heavy guns. A slight dropping of the deck amidships was noticeable, but this has now been raised to its original position, and considerably strengthened by additional supports.

King Alfred.—The following description and comparisons of this vessel with vessels of other services has been taken from the " Journal of the Royal United Service Institute."

The *King Alfred*, with her three sister ships, the *Drake*, the *Good Hope* and the *Leviathan*, will be the largest cruisers possessed by the British or any other Navy. This will be seen at a glance by the following table, which compares the *King*

Alfred's principal dimensions and weight with monster cruisers belonging to other first-class Powers:

Ship.	Length between perpendiculars.	Beam.	Draught.	Displacement.
	ft. *in.*	*ft.* *in.*	*ft.* *in.*	*tons.*
H. M. S. *King Alfred*.....	500 0	71 0	26 0	14,000
United States *California*..	502 0	69 6	24 6	13,800
Russian *Gromoboi*.....	473 0	68 6	26 0	12,336
French *Victor Hugo*.....	479 0	69 0	26 11	12,500
German *König Wilhelm*..	393 0	64 3	25 3	8,868

In respect of coal capacity, H.P. and speed, the *King Alfred* also heads the group of cruisers already tabulated, the comparisons being as follows:

Ship.	Engine power.	Speed.	Coal capacity.
	I.H.P.	*knots.*	*tons.*
H. M. S. *King Alfred*.....	30,000	23	2,500
United States *California*.....	23,000	22	2,000
Russian *Gromoboi*.....	14,500	20	2,500
French *Victor Hugo*.....	27,500	22	2,100
German *König Wilhelm*.....	15,000	20½	...

The armament of the *King Alfred* will consist of two 9.2-inch guns, mounted in turrets, one forward and one aft; sixteen 6-inch guns, mounted in casemates; fourteen 12-pounders; three 3-pounders; and nine machine guns. The 9.2-inch guns are 37.1 feet long, and, using cordite, develop a muzzle energy of 18,400 foot-tons; these guns are being provided by the Vickers Company with mountings before leaving the Barrow works, and with these it is expected they will easily maintain a continuous fire of four shots per minute. The gun mountings are of an entirely new type, and are arranged to be worked by hand as well as by hydraulic power. The whole revolving weight of the mounting with its gun is 120 tons, and all this weight can easily be worked by hand. There are eight 6-inch guns on each broadside arranged in a series of two-story casemates. These are 7-ton guns firing 100-pound projectiles, and by their special construction are capable of maintaining a rate of fire of eight rounds per minute.

Two of the guns on each broadside fire ahead as well as four 12-pounders and the 9.2-inch weapon, and thus the *King Alfred* when chasing on enemy will be able to fire ahead per minute the following weight of projectiles:

			Pounds.	Pounds.
From	9.2-inch guns . .	4 projectiles of	380	= 1,520
"	6 " " . .	32 "	100	= 3,200
"	12-pounder guns . .	80 "	12½	= 1,000
		116		5,720

Against a following enemy she will discharge the same weight of shot from the guns firing astern. The broadside fire per minute will be—

			Pounds.	Pounds.
From	9.2-inch guns . .	8 projectiles of	380	= 3,040
"	6 " " . .	64 "	100	= 6,400
"	12-pounder guns .	140 "	12½	= 1,750
		212		11,190

If all the large guns in the ship were fired simultaneously the total weight per minute would be approximately 16,000 pounds, and the total energy developed over 810,000 foot-tons. Comparing this with the gun power of other large cruisers, a correspondent of the "Morning Post" writes: The United States ships of the *California* class have four 8-inch guns in the two barbettes, instead of the two 9.2-inch guns in the *King Alfred*, but they have only fourteen 6-inch guns instead of the sixteen in the British ship. The most powerful of the United States 8-inch guns fires a projectile of 250 pounds instead of 380 pounds, the muzzle energy being 12,000 foot-tons, so that on a similar computation the 8-inch guns would fire twelve shots per minute, and the total weight of shot fired in a minute would be 14,200 pounds, or 1,800 pounds less than in the case of the British ship, which would also have the great advantage conferred by the higher power of the 9.2-inch weapons—each over 40 per cent. more effective than the 8-inch guns of the *California*. In the *Victor Hugo*, which the French are now constructing, it is proposed to mount four 7.6-inch guns as well as sixteen 6.4 inch

quick-firers. The French weapon of 6.4-inch caliber develops a velocity of 2,625 feet per second, whereas the Vickers gun for the British Navy develops 2,800 feet per second, though the same firm have completed guns for the Japanese Navy with a muzzle velocity of the very high rate of 3,000 feet per second. As the energy increases at a greater rate than the velocity it is obvious that the British ship has the advantage not only in the sixteen guns of 6-inch caliber, but in the power of the individual guns of larger caliber when compared with the weapons of the *Victor Hugo*. Thus the large guns in the French ship fire a projectile of only half the weight of 9.2-inch guns in the *King Alfred*, and thus it comes that one minute's fire, notwithstanding the greater number of guns, is, on a liberal computation, only 15,312 pounds, while the total muzzle energy is less—about 730,000 foot-tons, as compared with the 16,000 pounds and 810,000 foot-tons of the *King Alfred*.

The *King Alfred* will be fitted with forty-three water-tube boilers of the Belleville type, and her engines will be of the triple-expansion type, with one high-pressure cylinder of 43½ inches diameter, one intermediate, 71 inches in diameter, and two low-pressure cylinders, each 81½ inches in diameter, the stroke being 48 inches, and they are expected to develop their power when the engines are using steam at 250 pounds pressure and running 120 revolutions per minute. The total weight of machinery in the *King Alfred* will be 2,500 tons. With her coal supply of 2,500 tons, the ship will be able to steam at a cruising speed of 14 knots, for 12,500 sea miles, equal to a voyage from Portsmouth to Melbourne, without having to replenish her bunkers.

In the matter of armor protection there will be a belt of side armor 6 inches thick, commencing about 100 feet from the stern and extending forward to the ram, where it tapers off to 2 inches. The principal armament is protected by 6-inch steel, and there are two protective decks, extending almost the entire length of ship. Her complement will be 900 officers and men.

King Edward Class.—Two of the *King Edward* class will be fitted with Babcock & Wilcox boilers; the third with two-fifths cylindrical and three-fifths Babcock & Wilcox.

Monmouth.—The London and Glasgow Engineering and Shipbuilding Company, Limited, Govan, launched on Wednesday, the 13th of November, H. M. S. *Monmouth*, the first of the two first-class cruisers of the County class they have at present on hand for the British Admiralty, the principal dimensions being as follows: Length between perpendiculars, 440 feet; molded breadth, 66 feet; load draught, 24 feet 6 inches; displacement at load draught, 9,800 tons. The *Monmouth* is one of the vessels ordered in 1899, and her armor consists of a belt between main and lower or protective deck, extending from the bow to the aft end of the machinery space, where it terminates against an armored bulkhead. The main citadel armor is carried the whole length of engine and boiler space, and is 4⅛ inches thick; forward of the boiler space the armor is reduced to 3 inches thick, and about the bow to 2 inches, while the bulkhead armor is 3 inches thick. The lower or protected deck is of two thicknesses, the thickness varying from 2 inches outside of the range of armor to ¾ inch inside of that protection. The main deck, forming a crown to the armored portion of the vessel, is of two thicknesses, and is generally 1½ inches thick. The internal arrangements follow the usual Admiralty methods, the vessel being divided into numerous watertight compartments; the magazines and shell rooms being provided for at the ends of the vessel well under the water line, while the coal bunkers are carried along each side of the vessel, forming an additional protection in way of the machinery space. The normal coal capacity of the vessel is about 800 tons; but by utilizing the reserve bunkers this capacity can be increased to 1,600 tons.

The vessel will be fitted with steam and hand-steering gear. Steam is adopted for the forward anchor gear while electricity is the motive power aft. Four sets of engines and dynamos will be fitted of suitable power to produce the current necessary for a complete installation of electric lighting throughout the vessel, including six search lights, the boat and coal hoists, the after capstan gear and the necessary electric fans for the artificial ventilation of the ship below lower deck. The armament consists of two twin 6-inch guns forward and aft in barbettes, four 6-inch

guns in casemates on upper deck, and six similar guns in casemates on main deck, eight 12-pounder 12 cwt. guns, two 12-pounder 8 cwt. boat and field guns, three 3-pounder quick-firing guns, and eight Maxim guns; in addition to which the vessel is fitted with two submerged tubes, one on either side, for the discharge of 18-inch Whitehead torpedoes. The heavy guns are so arranged that a heavy fire may be maintained in any desired direction. The barbettes around the 6-inch twin guns are of 4-inch armor and are well connected to the structure of the ship and efficiently supported, while the ammunition to these guns is served through heavy armored trunks from magazines and shell rooms below. The casemate fronts are of hard steel, 4 inches thick, with rear plates 2 inches thick; and the conning tower, fitted above forecastle deck, is of 10-inch thick armor, with a communicating tube 6 inches thick, carried down to the protective deck, containing the connections to all the gear throughout the ship.

The machinery, which will be supplied by the builders, consists of two sets of triple-expansion four-crank engines. The diameters of the cylinders, and the order of their positions from forward are: Low-pressure, 69 inches; high-pressure, 37 inches; intermediate pressure, 60 inches; low-pressure, 69 inches; all having a stroke of 42 inches. The combined power of the two sets of main engines will amount to 22,000 indicated horsepower when running at 140 revolutions per minute. All the cylinders are fitted with steam jackets; the liners of the high-pressure and intermediate-pressure are of forged steel; those in the low-pressure cylinders are of cast iron. There are four surface condensers for the main engines, and two smaller condensers for the auxiliary engines. Each of the four main condensers is provided with sluice shut-off valves, so that any part of one may be overhauled while the other is at work. The total condensing surface in the four is 23,000 square feet; all of the condenser casings are of gun metal. The main engine's air pumps are worked by levers off the high-pressure engines; there is one pump for each set of engines. The six main and auxiliary feed pumps, two hotwell pumps, four fire and bilge pumps, one latrine,

and one drain tank pump, are all of Messrs. G. and J. Weir's special type. The main circulating pumps, together with fire and bilge pumps, give a total pumping capacity of 5,200 tons of water per hour from the bilges. The crank, intermediate and propeller shafting is all of the usual Admiralty type.

The propellers are of Parsons manganese-bronze. In addition to the main engines and auxiliary pumps in the engine-rooms, there are two sets of Messrs. Caird and Rayner's evaporators; each set consists of two evaporators and one distiller, the combined output of which will amount to 200 tons per 24 hours from evaporators and 70 tons per 24 hours from distillers; these are designed to work with the exhaust steam of the auxiliary system at a pressure of 25 pounds per square inch, or with boiler steam at the same pressure. The air compressors, of which there are two sets, are placed forward in the capstan engine room. The boilers are of the ordinary Belleville type, with economizers; there are thirty-one in number, arranged in three boiler rooms. The forward set in each boiler room is of the single-ended, and the after set of the double-ended type. As they have to work under assisted draft, there are four fans and two furnace air pumps in each boiler room. For ventilating purposes there are two fans in each engine room.

Mutine.—The new sloop *Mutine*, which is fitted with Belleville water-tube boilers, has run her commissioned steam trial, and got through it exceedingly well. Her machinery indicated a mean of 1,409 horsepower (1,400 horsepower was the power guaranteed at her contractors' trials), and she averaged a speed of 13.6 knots per hour. There was a pressure of 224.5 pounds of steam in the boilers, and the machinery worked at 200.4 revolutions per minute.

Odin and Merlin.—These two new sloops were floated out of dock at the Sheerness Dockyard on November 30 last. They were laid down on February 11, 1901, are sister ships, and were built side by side. Their principal dimensions are: Length, 185 feet; beam, 33 feet 4¼ inches; mean draught, 11 feet 3 inches; displacement, 1,096 tons; H.P., 1,400; speed, 13.25 knots; boilers, *Merlin*, Belleville; *Odin*, Babcock & Wilcox.

"P" Class of Cruisers.—REMOVAL OF VENTILATING COWLS.—The British Admiralty has ordered all the ventilating cowls and trunks to be removed from the upper decks of the third-class cruisers *Pactolus*, *Prometheus* and *Pelorus*, in order to carry out for three months a series of experiments in order to ascertain whether they are necessary in vessels of this type. Electric ventilating fans are counted upon to produce the necessary ventilation.

The Queen will be launched on March 8. The dimensions of the *Queen* are: Length between perpendiculars, 400 feet; extreme breadth, 75 feet; draught forward, 26.3 feet; draught aft, 27.5 feet; displacement, 15,000 tons. The present weight of the vessel is about 5,000 tons, and by the time she is ready to take the water probably another 1,000 tons will have been added. The times between the laying down and the launching of the other line of battleships built at Devonport were as follows: *Ocean*, 7,266 tons, 16 months 22 days; *Implacable*, 6,000 tons, 8 months; *Bulwark*, 5,930 tons, 7 months: *Montagu*, 5,560 tons, 15 months 1 day. The *Queen* will have taken 11 months 24 days.

The Rinaldo, sloop, has had her commissioned steam trial, which proved very successful, the particulars being as follows: Pressure of steam in boilers, 234 pounds; at engine, 216 pounds; vacuum, 25.1 inches; revolutions, 199.2 per minute; total indicated horsepower, 1,424; speed, 13.4 knots.

Vestal.—The full-power trial of the *Vestal* was a success, the vessel fully sustaining her previous good record. Her engines indicated a mean of 1,438 H.P., which was 38 H.P. in excess of the official standard. The mean pressure of steam in her boilers was 243 pounds, and her machinery averaged 198 revolutions per minute. The speed was 12.4 knots for the three hours' run, which was a little below the previous average.

Torpedo Boats, New.—The British Admiralty have ordered from the Thornycrofts four torpedo boats 160 feet long, which are practically small destroyers. The designed speed, fully loaded, is 25 knots.

108.—The first-class torpedo-boat *No. 108*, built by Messrs. J. I. Thornycroft and Co., Limited, for the Admiralty, has suc-

cessfully passed her official full-power coal trial of three hours' duration. The engines developed a mean of 2,876 indicated horsepower, which gave a speed of 25.359 knots with 385.5 revolutions of the engines. The air pressure was 2 inches to 2½ inches. The coal consumption was 2.009 pounds per indicated horsepower per hour. This is said to be one of the best results obtained with either destroyers or torpedo boats. The boilers are of the latest Thornycroft-Schulz type, in which the gases enter the tubes attached to the lower central barrel, and then proceed over the firebox down towards the wing barrels, and thence up the funnel.

Syren, the last of a series of thirteen 30-knot torpedo-boat destroyers supplied by Palmers Shipbuilding Company, has completed her trials. The first boat of the series was the *Star*, which had a serious accident on her first trial, but since then the whole of the boats have been run with such remarkable success that the only cause of abandonment of trial has been bad weather. At the full-power trial the *Syren* drew 5 feet 1⅜ inches forward and 9 feet ¾ inch aft. She had 245 pounds of steam in her boilers and the vacuum was 25 inches starboard and port. The revolutions were 382.9 starboard and 380.2 port, and the total I.H.P. was 6,708. The air pressure was 3.6 inches, and the mean speed of the three hours was exactly 30 knots. During the early part of the trial the vessel made six runs over the measured mile in Stokes Bay, when the mean I.H.P. was 6,689 and the speed 29.812. These results correspond with those obtained at the coal-consumption trial, when the mean speed of the three hours was 29.764 knots and the I.H.P. 6,665. Between the two trials the coal was weighed, and the consumption was found to be 2.4 pounds per I.H.P. per hour. The speed and economical results do not appear to compare favorably with the *Syren's* predecessors, built by the same firm, but it should be explained that the vessel carried 40 tons more than the *Star*, the first of the series, and 30 tons more than the *Myrmidon*, the eleventh on the list. An interesting feature of both trials of the *Syren* was the use of the automatic lubricator, the invention of Mr. Reed, who is the patentee of the boiler used in all the destroyers built

by Palmers Shipbuilding Company. The oil, after being pumped in at the end of the shaft, is forced through all the rods and bearings, and, after returning to the reservoir, is sent on its course again. The saving of manual labor is comparatively unimportant, but the certainty that every part of the machinery is regularly and systematically lubricated has been clearly demonstrated, and hence a great saving of wear and tear may be expected.

Greyhound.—This new torpedo-boat destroyer has undergone a successful three-hours' official coal-consumption trial, with engines working at full power. During six runs in the measured mile an average speed of 30.424 knots was obtained, while the average for the full time was 30.157. The machinery worked smoothly, the steam pressure in the boilers being 243 pounds per square inch. The revolutions per minute were 392 starboard and 394.4 port. The mean I.H.P was 3,229 starboard and 3,144 port, making a total of 6,373. The actual consumption of coal has not yet been worked out. The vessel returned to Chatham to be prepared for further trials.

No. 107.—This new torpedo boat has passed her final official full-speed trial off the mouth of the Thames. The mean speed on the measured mile was 25.401, and that for the three hours 25.206, the I.H.P. being 2,899. The notable features of the trial were the smoothness with which the engine worked, the low air pressure in the stokeholds (1.6 inches), and the handiness of the boat in turning. The diameter of the circles at full speed were not more than three lengths under starboard helm, and four lengths under port helm, the boat remaining practically upright. The trial was made with the full sea-going load of 42 tons on board, which is much in excess of the 35 tons carried on the trials of 30-knot torpedo-boat destroyers of twice the displacement. The stiffness and strength of the hull were clearly shown by the remarkable absence of vibration.—"Naval and Military Record."

Destroyers, New.—Tenders for the ten new destroyers of last year's estimates are reported to have been issued, and a good deal of individuality is to be allowed to the builders. The new boats

will, it is said, be of 500 tons or more, with sea speeds of 25 to 27 knots. In form they will be more like the torpedo gunboats than destroyers.

Express.—Great dissatisfaction prevails in British naval circles over the delay in the case of the torpedo-boat destroyer *Express*, which, although ordered in July, 1896, and launched in December, 1897, has not yet been accepted by the Admiralty. As a rule, torpedo boats built for the British Government are expected to be ready for acceptance, with all steam trials completed, within a year after launching, and the *Decoy*, the *Hawk*, the *Hornet*, the *Daring*, the *Ferret* and the *Lynx*, all of them completed under those conditions, have proved more satisfactory than others for which longer time was taken. Of all failures with craft of this type that of the *Express* is the most glaring. Launched, as we have said, in 1897, she began her preliminary trials on October 20, 1898, and has since made twenty-seven preliminary and ten official trials, but satisfactory official trials have not yet been made. The vessel is guaranteed to attain a speed of 33 knots an hour.—"A. & N. Journal."

Express.—After many days and many trials, the Birkenhead 33-knot torpedo destroyer is reported to have attained her guaranteed rate of speed on trial over the Clyde measured mile course.

Submarines, New Type.—A new type of submarine has been ordered by the Admiralty from Vickers, Son & Maxim, Limited. An order was originally given to the firm for five out of six submarines. Now the sixth is to be built. The vessel is to be 100 feet long—37 feet longer than the other five—and will embrace some new departures in design and construction, based on experiments already made. The new boat is to be ready and in working order at the Coronation Naval Review.

FRANCE.

Bourrasque.—The French torpedo boat *Bourrasque*, on trial at Cherbourg, has made, with 347 revolutions, a mean of 31.53 knots. She is a Normand boat.

She has arrived at Cherbourg from Havre, where she was constructed by the Forges et Chantiers de la Méditerranée, having

averaged 27 knots on the passage round. She is somewhat different from the *Siroco* class, being lighter and faster, having a speed of 29 to 30 knots, as against 26 knots of the earlier vessels; on the other hand, her radius of action is less than that of the *Siroco*, being only 2,000 miles at 10 knots speed as against the 2,500 of the latter, and she only carries two torpedo tubes instead of three. The "Yacht" holds that the earlier vessels are the best. The *Typhon*, another new boat, has beaten the record, having covered the distance, 72 miles, in 2¼ hours, a speed of nearly 32 knots.

Bruix.—It is reported that this armored cruiser is failing totally to make her speed.

Dupuy de Lôme.—There is a report being circulated to the effect that the boilers of this fine vessel are in such a bad state that she can not be in any way pressed.

Indomptable.—The work of reconstructing this coast-defense battleship, has now almost been completed, and it is hoped she will commence her trials before the end of the year. She has received new boilers of the old cylindrical type, and her two 42-cm. (16.5-inch) 75-ton guns, which were carried in barbettes, one forward and one aft, have been replaced by two 27.4-cm. (10.8-inch) 45-caliber guns of the latest model in closed turrets, which, with the guns, can be worked either by electricty or hand.

Jean Bart.—It is reported that the cylindrical boilers of this vessel will be replaced by water-tube boilers of the Niclausse type.

The Cruiser Jurien de la Graviere.—The *Jurien de la Graviere* is an improvement upon the *Guichen* and *Chateaurenault*, with which "The Engineer" has already dealt. By improvement we mean that she is of the same general type, but smaller than the *Guichen*, which has been considered too large and too lightly armed for her work. The latter carries two 6.4-inch and six 5.4-inch guns on a displacement of 8,277 tons; in the *Jurien de la Graviere* eight 6.4-inch pieces are carried on a displacement of 5,500 tons.

The chief interest of the ship is, however, in comparison with

British designs, and we have therefore selected the *Hyacinth*, which is the nearest vessel we have to her in date and displacement. The following are the particulars:

	French.	British.
Nationality		
Name	*Jurien de la Graviere.*	*Hyacinth.*
Displacement, tons	5,500	5,600
Length, feet	440	350
Beam, feet	48½	54
Draught, feet, mean	22	22
Indicated horsepower	17,000	10,000
Nominal speed, knots	23	20
Screws	Three.	Two.
Boilers	Guyot.	Eighteen Belleville.
Armament	Eight 6.4, 45 cals.; twelve 6-pdrs.	Eleven 6-in., eight 3-in., six 3-pdrs.
Torpedo tubes (submerged)	None.	Two.
Torpedo tubes (above water)	Two.	None.
Protection to guns	Shields.	Shields.
Protection, water line deck	3-in. of cellulose.	3-in.
Complement	511	450
Machinery	Three sets vertical triple-expansion.	Four cylinder triple-expansion.
Coal, normal, tons	600	500
maximum, tons	900	100

These figures indicate how vast are the differences between the ships—the British one relatively short and broad, the French long and narrow. This, of course, entails better stability and maneuvering power for the *Hyacinth*, better speed for the Frenchman by sheer virtue of form, apart from the additional horsepower. We know, too, that, presumably owing to faults in her lines, the *Hyacinth* is not much of a flyer, and not able to make her proper speed. The *Jurien de la Graviere* has not yet made her trials, but there is no reason to suppose that she will fail to make her 23 knots, unless the machinery prove defective, and she may very well exceed it. The *Hyacinth* class are not brilliantly successful ships by any means; the *Jurien de la Graviere*,

on the other hand, promises to be so, yet for war purposes we must assert that the *Hyacinth* is far and away the better ship. We admit that the *Hyacinth* is perhaps not merely three, but four, knots behind what the French cruiser will do on trial. We admit that she would have great difficulty in attempting to catch the Frenchman, and that her guns are altogether inferior in penetration, but, bad form though it be to see superiority in British productions, we assert the practical superiority of the *Hyacinth*, and we do it for the following reasons:

The primary duty of a warship is to fight. She may be designed to chase the tramp or the liner, to scout, to chase torpedo craft, to do anything; but in the day of war "powder burning" will be her ultimate object. Evasion is beautiful in theory, it will never work in practice, it never has worked. If two ships sight each other they will—if of equal size—fight, whether designed to fight or not, whether ordered to abstain or not. It is human nature; it is also human necessity. French officers are brave, and in the war of the future if the *Jurien de la Graviere* meets the *Hyacinth*, and, acting on orders, turns to run, a single taunting signal will at once destroy her superior speed, so far as running away is concerned. It always did in the past, and it always will. Human nature, as we have said, necessitates. It will absolutely ruin the Frenchman's crew if they are made to run from a British ship of the same size. The moral effect of such a thing would permeate the whole French Navy. Geniuses on shore, seeing clearly the theory involved, may order flight, but practical sailors will never obey it. We believe in the *Hyacinth*, the 450 men aboard her will believe in her; but the 511 on board the Frenchman will be every whit as convinced that theirs is the better ship.

Let us trace out the probable issue of the fight. The advantages the two rival ships may claim are as follows—superior penetration of the French guns being totally valueless:

British.	French.
Handiness.	Speed.
Superior gun fire.	Rather better rate of fire.

It is a pretty and even match. The better captain and the

better crew will be those who will win. For comparative purposes we must, however, assume absolute equality in this respect.

Now the broadside fire of the British vessel reduced to 6-inch units is 7 and a tiny fraction; that of the Frenchman something under 6. The Frenchman has electric hoists, and may so neutralize this by a more rapid fire, which, however, the Briton may meet—is certain to meet—by collecting a heap of ammunition around each gun. It is a dangerous risk, but it will have to be taken. For this reason, we do not give the British vessel much, if any, advantage for her superior fire; steaming side by side, the two will annihilate each other—assuming equally good gunnery—at about equal rates. Nor are we disposed to claim much for the submerged tubes of the *Hyacinth*. Honestly, we have no certainty that it will be possible to work them; the gun, we fancy, will be the first factor and the last.

Now the advantage of speed is to be able to get in the most satisfactory position for using the gun. The ideal position with protected cruisers is—as it was a hundred years ago—a raking one. The raked cruiser will be the defeated one—once raked she will be of no further use for fighting. Speed can enable a ship to rake; but there is something else that can enable her to do so still more, and that thing is handiness. Hence, we hold the *Hyacinth* to be the better ship because she is, of the two, more likely to rake than to be raked.

This, of course, is a practical asset; on paper it does not show, because the kind of critic who lets himself loose against British designs is not usually sufficiently equipped to realize that a ship 350 feet by 54 feet must have an infinitely smaller turning circle than one 440 feet by 48¾ feet. He sees 20 knots against 23 knots, 6-inch guns against 6.4-inch, and that is enough for him.

Léon Gambetta.—The first-class armored cruiser *Léon Gambetta*, 12,550 tons, was launched at Brest on the 26th October. She has been constructed with great rapidity. For some years the arsenal at Brest has made great progress in this direction, and the launch of the *Léon Gambetta* marks a still further gain. The following table allows of a comparison being made of the recently constructed vessels at Brest:

Ship.	Weight of hull when launched.	Number of days before launching.
	Tons.	
Charlemagne	2,706	315
Gaulois	2,488	315
Iéna	2,828	281
Suffren	3,070	284
La Marseillaise	2,905	267
Léon Gambetta	3,480	300

The plans of the latter were sent to Brest on 20th July, 1900, and she was laid down on 15th January last. The vessel was therefore nine months and ten days on the stocks. She is to be ready for trial in 1903. The total period of construction will thus not exceed three years. Her cost is 29,248,500 francs (£1,169,940), and she is the largest armored cruiser yet built by France.

Montcalm.—The preliminary trials of this vessel were four in number, at 6,000, 9,500, 14,000 and 18,200 I.H.P., respectively. The engines are designed for 19,600 I.H.P., which was expected to give a speed of 21 knots, under forced draft. At the 18,200 I.H.P. trial, with a slightly foul bottom, a speed of 20.8 knots was recorded. The engines worked well and there was a noticeable absence of vibration of the hull. The ship answered her helm with remarkable ease.

After the preliminary trials, the acceptance trials were begun. On the last run at full speed over the measured mile, with the engines developing 20,378 I.H.P., or 800 in excess of the contract, the ship developed a speed of 20.3 knots. The last trial was a 24 hours' coal-consumption trial. At 11,300 I.H.P., the coal consumption was only 1.48 pounds per H.P. per hour, and the speed developed was 19 knots. The ship behaved perfectly throughout the entire series of trials.

Pistolet and Bélier.—The Minister of Marine has concluded a contract with the Compagnie des Chantiers de la Loire for the construction of two new torpedo-boat destroyers; they are to be called the *Pistolet* and *Bélier*. With a displacement of 302 tons, a length of 175 feet, a beam of 20 feet 6 inches, and a mean draught of 9 feet, they are to steam 28 knots.

Pique.—According to "France Militaire," the commander of the French torpedo-boat destroyer *Pique* during a recent cruise had serious misgivings as to the boat's stability; the sea was rough and at times the angle of inclination became so large as to be dangerous. On receiving the report of the commander the Minister of Marine ordered an investigation to be made, with the result that most of the boats of this type were found to have insufficient stability, owing to the superstructure being too high. Orders have now been given for alterations necessary to remedy this condition of affairs to be made.—"Naval and Military Record."

Requin.—On her preliminary trial this coast-guard battleship, with only 10 boilers out of 12, developed 6,230 H.P. in place of the 6,000 H.P. called for, with a coal consumption of only 1.6 pounds per H.P. per hour.

Submarines.—It is in contemplation to lay down thirteen submarines for the French Navy at Toulon in 1903. It was originally proposed to lay down only five of these vessels in 1903, leaving eight to be undertaken in subsequent years. It is now considered desirable, however, to accelerate the work of construction, and an effort is to be made to have all the thirteen submarines ready for service in the course of 1904.—"Naval and Military Record."

Submarines, New.—The twenty-three new submarines being built in the French dock yards are all very much of the same type. Their displacement is 68 tons. Each boat will carry one officer and four men. An electric motor propels one screw, and the speed is not to exceed eight knots. Three submarines of a special type are shortly to be laid down on novel plans drawn by three different engineers, but no particulars regarding their designs have been published by the French Admiralty. The cost of each ranges from $100,000 to $185,000.

Submarines.—The new submergible boats of the *Narval* type are continuing their trials, both the *Triton* and the *Sirène* having given, on the whole, satisfactory results; the *Sirène's* last trial was for 24 hours, four of which were spent under water, her time for actual submersion from the beginning of the plunge was five

minutes, and her stability and habitability are reported to be good, but they are not considered by competent judges to be as good as the submarine boats proper, like the *Morse*, *Francais* and *Algérien*, which can be maneuvered with much more certainty. Their great—one may say fatal—defect is the slowness of their submergence. If they are ever sighted by an enemy's cruiser, battleship or destroyer, their doom is sealed. Under the most favorable conditions it takes fifteen minutes from the time they begin to fill their ballast tanks for submergence, and longer if attempting to go ahead. A destroyer can run six or seven miles in fifteen minutes, and a cruiser or battleship at least four miles. The *Narval* type could, therefore, never approach within striking distance of an enemy without reasonable certainty of being destroyed unless they operate as submarines. The *Espadon*, the latest to be completed here, has made her trial plunge. She took eight minutes to sink to a depth of 26 feet, and she remained submerged for 2½ hours; on rising she came to the surface at once, where her full speed is 10 knots. The *Silure*, the last of the four of this tpye, has been launched. She is of the modified *Narval* type, and possesses the advantage of being able to recharge her own accumulators, whereas vessels of the *Morse* type, such as the *Francais* and *Algérien*, have to recharge theirs at some electrical station.

It is stated that the new submarine boats already commenced, or to be commenced this year, will have a double motive power like the submergible boats; that is to say, a vapor or gas engine and electric accumulators. They will not be, however, submergible boats of the *Narval* and *Sirène* type, but true submarines in the proper sense of the word; only they will have a motor for propulsion when at the surface and for recharging the accumulators—the latter being used only when submerged. In a word, they will realize up to a certain point the autonomous type of submarine boat. They will have a radius of action a little more extended than that of the purely submarine boat, and will plunge more quickly than the *Narval* and *Sirène*, which are obliged to fill the ballast tanks between the hulls—a long operation as we know.

Suffren.—The new first-class battleship, *Suffren*, has been commissioned for her trials with a reduced complement. In every way this ship is superior to any of her predecessors; thus, while in the *Iéna* the heavy armor belt only rises to about 2 feet 9 inches above the water, the *Suffren's* is some 6 inches higher, and the whole side above from the bows to the after turret is protected up to the main deck by a belt of 5-inch armor, tapering to 3.5 inches forward, thus protecting the bases of the turrets and casemates for the secondary armament, which, in the *Charlemagne* class and *Iéna* are quite unprotected. Moreover she carries ten 16.4-cm. (6.3-inch) Q.F. guns in place of the *Iéna's* eight, six being in small turrets and four in casemates.

Torpedo Boat No. 254 has finished its trials and has been accepted for service. It obtained, at full power, a speed of 25.015 knots with an average of 342 revolutions of the engines.

Torpedo Boat No. 256 was launched at Havre on 29th of November; she is 37 meters long and 4.30 meters wide, and has a displacement of 90 tons; her engines are of 1,800 H.P., and speed 24 knots. The armament comprises two 37-millimeters Q.F. guns, and there are three above-water torpedo tubes. Her complement is fixed at 2 officers and 31 men.

Typhon.—On the recent trials of this sea-going torpedo boat, the last of the six vessels of this type having the armored hull, a mean speed of 27.78 knots was made with 349.7 revolutions of the screws.

GERMANY.

Brandenburg Type of Battleships.—After the completion of the work of modernizing the small coast-guard battleships is completed, the *Brandenburg* type will also be brought up to date as nearly as possible.

Gazelle, Improved.—The German Admiralty has under consideration a new type of small cruiser, an improvement on the vessels of the *Gazelle* class. These last have a length of 328 feet; beam, 38 feet 7 inches; displacement, 2,660 tons; speed, 22 knots; and a complement of 249 men. The new type will have a length of 360 feet; beam, 40 feet 4 inches; displacement, 2,715 tons; speed, 24 knots; and a complement of 260 men.

The armament has not yet been decided upon, but it will be more powerful than that of the *Gazelle* type and possess all the latest improvements, full advantage being taken of the results of experiments in other navies.

Kaiser Karl der Grosse, new first-class battleship, has commenced her trials. She is the last of the four ships of the *Kaiser* class to be completed. She was laid down in 1898, launched on the 18th October, 1899, and is to be completed by the spring of next year.

Kaiser Barbarossa, new first-class battleship, has completed her trials successfully. Like all the later German battleships, she has three screws, steam being provided by six cylindrical boilers placed abaft the engines, which have a total grate surface of 153 square feet, and a heating surface of 5,070 square feet, and by six Thornycroft water-tube boilers forward of the engine room, which have a grate surface of 124 square feet and a heating surface of 7,224 square feet, all worked at a pressure of 187 pounds per square inch. The result of the trials was as follows: During the fifty hours under natural draft the engines developed 7,360 I.H.P., making 94 revolutions, and giving a speed of 15.5 knots; pressure of steam, 187 pounds per square inch, and consumption of coal per H.P. per hour, 834 grammes (30 ozs.). At the six-hour full-speed forced-draft trial, the engines developed 13,940 I.H.P., making 112.8 revolutions, and giving a speed of 18 knots; the pressure of steam being the same as at previous trial, and coal consumption not being recorded; the air pressure for the water-tube boilers being 1.7 inches and for the cylindrical boilers .47 inch.

Ariadne.—This new third-class cruiser has completed her forced-draft trial successfully, the results being as follows: Draught, forward, 13 feet; aft, 16 feet 3 inches; I.H.P., 8,827; revolutions, 168; speed, 22.18 knots; consumption of coal per H.P. per hour, 944 grammes (33 ozs.); air pressure, 1.69 inches.

Thetis.—Another third-class cruiser of the same class, has completed her trials very satisfactorily; in the earlier vessels of the class the engines developed 6,400 I.H.P., giving a speed of 19 knots, but the engines of the *Thetis*, on her six-hours'

forced-draft trial, developed 8,888 I.H.P., making 173 revolutions, and giving a speed of 21.7 knots; a sister ship, the *Amazone*, has also been commissioned and is to commence her trials immediately.

German Cruiser Konig Wilhelm Ersatz.—Some time ago we illustrated and described in the "Engineer" the German armored cruiser *Prinz Heinrich*, and pointed out how greatly she advanced upon *Fürst Bismarck*, her predecessor. Though externally less visible, almost as great an improvement exists between the latest vessel and the *Prinz Heinrich*. Of the new 9,048 type there are two vessels, substantially similar, under construction—the *Prinz Adalbert* and the, as yet unofficially unnamed, *Konig Wilhelm Ersatz*.

The table below indicates the progress in armor, armament, machinery, etc., in the three types, but attention may also be drawn to other changes. Not the least interesting of these is the form of rudder and cut-away deadwood. For the rest we may observe that, as evidenced by the now well know *Fürst Bismarck*, earlier German construction was—in a sense—essentially "amateur;" that is to say, recently completed ships embody those kind of features which we might expect to see evolved by the gentlemen who contribute to our daily press those awe inspiring lists of comparative fire energies and the like. The *Bismarck's* guns are heavily protected, while their bases are nearly ignored; in later vessels much is discarded in favor of protected gun bases, and in place of five distinct partially-defended gun positions, there are now but three groups, each completely protected. The *Bismarck* is more or less at the mercy of all shell, though proof against anything but the largest A. P. projectiles. The new ships can be successfully attacked by merely 8-inch A. P., but they are shell proof—undoubtedly the better virtue of the two. "Increase the armored area at all costs," seems to be the motto of modern German design, and unquestionably this is correct.

The data of these cruiser designs, to which we have added a few others for comparison, are given on the opposite page.

Paper comparisons are notoriously incomplete. The *St. Louis* is here so much the worst of the batch that we suspect her to be

.....	*Bismarck.*	*P. Heinrich.*	*P. Adalbert* and new ship.	Japanese, *Iwate.*	British, County class.	United States, *St. Louis.*	French, *Montcalm.*
Displacement, tons	10,700	8,930	9,048	9,800	9,800	9,700	9,517
Length, feet	394	394	394	400	440	423	453
Beam, feet	65½	65½	65½	68½	66	65½	64
Draught (mean), feet	25	23½	23½	24½	24½	23½	24½
Primary guns	Four 9.4-in.	Two 9.4-in.	Four 8.2-in.	Four 8-in.	Two 7.5-in.	.....	Two 7.6-in.
Secondary guns	Twelve 6-in.	Ten 6-in.	Ten 6-in.	Fourteen 6-in.	Ten 6-in.	Fourteen 6-in.	Eight 6.4-in.
Tertiary guns	Ten 3.4 in.	Ten 3.4-in.	Twelve 3.4-in.	Twelve 3-in.	Ten 3-in.	Eighteen 3.in.	Four 4-in.
Small guns	Ten 1-pounders, four Maxims.	Ten 1-pounders, four Maxims.	Ten 1-pounders, four Maxims.	Twelve small	Three 3-pounders, eight Maxims.	Twelve 1-pounders, ten automatic.	Sixteen 3-pounders, six 1-pounders.
Submerged torpedo tubes	Five	Three	Three	Four	Two	.....	Two.
Above-water torpedo tubes	One	One	One (armored)	...	...	...	...
Armor	Krupp	Krupp	Krupp	Krupp	Krupp	Krupp,	Harvey nickel.
Belt amidships	8-in.	4-in.	4-in.	7-in.	4-in.	4-in.	6-in.
Belt at ends	.....	.....	3½-in.	3½-in.	2-in.	.....	4-in.
Deck	2-in.	2-in.	2-in.	2½-in.	2-in.	3-in.	2-in.
Lower deck, side	.....	4-in.	4.in.	5-in	4-in—2-in	4-in.	4-in.—2-in.
Length of this belt	.....	150 feet	215 feet	200 feet	350 feet	115 feet	440 feet.
Bulkheads, lower deck	None	4-in.	4-in.	5-in.	5-in. (aft)	4-in.	6-in (aft).
On main guns	8-in.	6-in.	6-in.	6-in.	5-in.	.....	6-in.
Protection to main-gun bases.	8-in shallow barbettes, then an armored hoist only.	6-in., tubes conical.	6-in., tubes conical.	6-in., complete barbettes.	8-in., shallow barbette and hoist only.	.....	4-in., big tube.
Secondary guns	Six in turrets, two in casemates, four in battery; on all, 6-in. armor; unprotected bases.	Four in turrets, six in battery; on all, 4-in. armor.	Four in turrets, six in battery; on all, 4-in. armor.	Ten in 6-in. casemates, four unprotected.	All ten in 4-in. casemates.	Four in 4-in. casemates, eight in 4-in. battery, two unprotected.	6.4-in. in 4-in. casemates, with unprotected bases; four 4-in., unprotected.
Screws	Three	Three	Three	Two	Two	Two	Three.
I.H.P.	13,500	15,000	17,000	14,500	22,000	21,000	19,600
Speed, knots	18.7	20	21	20.75	23	21.5	21
Coal (normal), tons	1,000	1,500	1,500	550	(?)	650	1,000
Coal (maximum), tons	1,100	1,700	1,700	1,300	(?)	1,500	1,690
Boilers	Eight Thornycroft, eight cylindrical.	Fourteen Dürr	Fourteen Dürr	Belleville	Various	Babcock & Wilcox	Normand.
Complement	589	501	550	(?)	(?)	(?)	612

far and away the best of the lot in nautical qualities. It is so characteristically non-American that we are forced to believe this. She will probably turn out able to beat all the others at steaming on long courses. However, so far as paper goes, the new German design holds its own very well with all the others. Her dimensions, it will be noted, are very akin to the Elswick *Iwate* class. These, it is noted, roll a great deal, the German design being weighted with as much, or even more, upper works, may, therefore, roll more or as much. In lines the two are very alike. Still, there is a strong belief that our County class will roll tremendously, that the *Montcalm* class will, goes without saying; so the German ship is not likely to be peculiar. Possibly some of the *St. Louis*' hidden virtues reside here.

In the matter of handiness the Elswick cruisers are very good, we may take it that the Germans will be equally so—certainly better than the British, French and American designs. This the dimensions indicate.

A word may be said here about the class of 4-inch armored cruisers now springing up. We have some eighteen building or projected. America has four in hand, Germany three—that is, twenty-five ships all told, covered with a good deal of thin armor. It is the type of the moment. It corresponds in a measure with the *Latona* class of a decade or so ago. That class has little use now, and we are inclined to think that the new type will be no longer lived. Four-inch armor is very thin. It will not keep out 8-inch or 7.5-inch projectiles now; in the future the 6-inch gun is likely to be able to defeat it. It will be worth the gun's while to do so, and that almost entails the intervention of the necessary projectile. Apart from this, have high explosives been fully considered? On the proving ground they will shatter 4-inch plates all to pieces, even from 6-inch guns. Cruisers will have to face 8-inch and 9.2-inch shell frequently enough, and the efficacy of 4-inch armor against these is very doubtful. In view of this, the *Asama* seems a safer type, hence the 4-inch armored cruiser seems likely to be a transient type.

However, the type exists, and of the three, in the matter of handiness, armament and disposition of armor, the German de-

sign seems superior to the County class or the American *St. Louis*. The Germans' big gun bases are shell-proof, while the County class have a mere tray, easily incommoded by shell. Attention may be directed to the form of the Germans' barbette bases. They embody the shape that has long been held ideal—too ideal to construct. The question is, how will they be constructed? for as yet they only exist in design. Anyone familiar with armor construction is aware that the Krupp process lends itself badly to anything save vertical plates, so much so, indeed, that in all our ships turrets are constructed of nickel-steel in preference to the superior armor. The theory—if it be not a deal more than a theory—obtains that when very hard armor is used for curved plates, work on them takes away all their virtue. The inverted cone of the German turret bases offers a far more difficult piece of work than any turret. It is not known whether Herr Krupp, who supplies the bulk of German armor, has solved the problem and is making these bases of Kruppized cemented steel, or whether nickel is resorted to. The point is important, but in any case the defence is altogether superior to that in our County class. The German 4-inch battery is probably not so good as the casemate system in our County class. One 6-inch high explosive between the second and third funnels would beyond question put the four upper-deck turrets out of action, and its effects might reach to the battery below. A single-medium projectile in the main-deck battery would probably wipe out all the 6-inch in the German ship. Both are in the category of possible hits. The County class, on the other hand, need at least six hits by medium projectiles—putting aside particularly "lucky shots"—to disable the ten casemates. Both cases are instances of compromise, of course, due as ever to the fact that a warship has to move fast, and to ensure that moving, leaves none too much weight for guns and armor.

In comparing the *Prinz Heinrich* with her later developments, we may draw attention to the following—all improvements:

(1) Four 8.2-inch, substituted for two 9.4-inch.

(2) Great increase in the length of the lower-deck side belt,

thus encasing the bases of the ammunition tubes of the big guns.

(3) Cellulose belt.

(4) Slight reduction of superstructure, etc.

Having unfavorably criticised the concentration of the 6-inch guns, we feel that, in conclusion, some reference should be made to the advantages that presumably led to its adoption, even with the thin armor that is its chief fault. Control of fire in the battery should be extremely easy. In our County class it is going to be anything but easy. If—as may very possibly happen—fire control in battle becomes a matter of sending messengers, the German idea offers great advantages. All the 6-inch guns can be got at nearly at once. In the County class they certainly cannot be. Hence it comes that, given thicker armor, the German design should not be far off the ideal cruiser, for her weak point would then only be the four little turrets nested together amidships. In action, the life of these is likely to be very short, and the armoring of them probably a waste of weight. The first shell is practically certain to jam them.

Finally, the cellulose over the bow is an indication that the Germans have been studying things nautical a good deal more than they did a few years ago, when their vessels certainly suggested the soldier's idea of a warship. That particular form of originality is now abandoned. When next German design essays originality the result, we may safely prophesy, will be nautically far more satisfactory.—"The Engineer."

"K" and "L."—Two new battleships designated by these letters will be laid down this year. They will be of 13,000 tons displacement, 16,000 I.H.P. and 19½ knots speed. They are to be of the same type as the two vessels now building at Danzig and Kiel.

GREECE.

Cruisers, Destroyers and Torpedo Boats.—Greece has recently laid down, according to rumor, three armored cruisers, four destroyers, and six torpedo boats. Where they are being built has not been stated.

HOLLAND.

Hertog Hendrih.—The Dutch Government has decided to adopt Yarrow water-tube boilers in this latest battleship now building, of 6,000 horsepower.

ITALY.

Ammiraglio di St. Bon.—This new first-class battleship has successfully completed her steam trials off Spezia. Her dimensions are as follows: Length, 344 feet 6 inches; beam, 69 feet 4 inches; mean draught, 24 feet 9 inches, with a displacement of 9,800 tons. The engines are twin-screwed, triple-expansion, developing 9,000 I.H.P. under natural draft, giving a speed of 16 knots, and 13,500 I.H.P. under forced draft, to give a speed of 18 knots. The normal coal supply is 600 tons, but 1,000 tons can be carried, which will give a radius of action of 4,000 and 7,500 miles at 10 knots speed, respectively, and, in addition to the coal, a certain amount of liquid fuel can be carried in the double bottoms. Steam is provided by twelve ordinary cylindrical boilers, which are placed in groups before and abaft the engines, each group being in two compartments, separated by a watertight bulkhead amidships. The diameters of the cylinders are: 1,118, 1,676 and 2,515 mm. (44, 66, 99 inches) respectively. The contract requires the engines to develop 13,500 I.H.P., with an air pressure not exceeding 40 mm. (1.58 inches), the pressure on the boilers being 155 pounds on the square inch, and the number of revolutions not to exceed 212. The total heating surface is 2,200 square meters (23,680.5 square feet), with a total grate surface of 78.6 square meters (842 square feet). According to the contract the consumption of coal at the natural-draft trial was not to exceed 900 gr. (32 ozs.) per H.P. per hour. The total weight of the engines with water in the boilers and all the tubes, etc., is 1,340 tons.

The results of the trials were as follows: Natural draft for six hours: number of boilers, twelve; pressure in boilers, 150 pounds per square inch; pressure at engines, 148 pounds per square inch; mean air pressure, 8.5 mm. (.3 inch); number of

revolutions, 94.4; I.H.P. developed, 10,407; mean draught, 24 feet 4 inches; displacement, 9,950; mean speed, 17.4; consumption of coal per H.P. per hour, 850 gr. (30 ounces). Forced draft one and a half hours: number of boilers, twelve; pressure at boilers, 150 pounds per square inch; pressure at engines, 146 pounds per square inch; mean air pressure, 32 mm. (1.3 inches); number of revolutions, 104; I.H.P. developed, 14,296; mean draught, 24 feet 3.5 inches; displacement, 9,908; mean speed, 18.3; consumption of coal per H.P., 989 gr. (35 ounces). The engines worked quite smoothly and satisfactorily throughout, and the trials were considered eminently successful.

Garibaldi and Varese.—At the end of October a competitive steam trial took place between the first-class armored cruisers *Garibaldi* and *Varese*, in order to determine what system of boilers should be supplied to the new battleships *Regina Elena* and *Vittorio Emanuele III.* The *Garibaldi* is fitted with the Niclausse type of water-tube boilers, and the *Varese* with the Belleville, so in view of the fact that the English Admiralty has decided against the Belleville for their new ships, the trial was looked forward to with lively interest. The *Varese* received orders to steam ahead, and when she was twelve miles ahead of the *Garibaldi* the trial began. The run was for 24 hours, and during that time the revolutions of the engines of the *Garibaldi* were at the rate of from 86 to 88, the I.H.P. developed being 7,000, and the speed 17 knots. Only 16 of the 24 boilers were used, and this was also the case on the *Varese.* The engines and boilers of both ships worked well, the pressure of steam in the boilers being 170 pounds. The consumption of coal in the furnaces of the *Garibaldi* was 6 tons 4 cwt. 35 lbs. per hour, or 1.78 pounds per H.P. The consumption on board the *Varese* is not stated, but it was rather less. The *Garibaldi* overtook the *Varese* and finished some hundreds of yards ahead of her. The "Italia Militare e Marina" of 5th of December states that any judgment with regard to the comparative merit of the two types of boilers is premature, as an accurate examination of all the results of the trials has not yet been made and reported upon. The balance of advantages and

disadvantages is about equal in the two types. It is considered proved that the Belleville boilers have a greater working efficiency, and that the Niclausse boilers admit of exceptional facility in partial refitting.—"Journal R. U. S. I."

Benedetto Brin.—The new battleship *Benedetto Brin* which has already been described in the JOURNAL, was launched at Castellamare on November 7.

Francesco Ferrucio.—This armored cruiser of 7,400 tons displacement, 13,500 I.H.P., and 20 knots, will probably be launched early in April. Her place on the stocks will be taken by a third cruiser, of 12,625 tons displacement, 20,000 I.H.P., and 22 knots, of the same type as the *Vittorio Emmanuele III.* She will probably be named *Roma.*

Nembo.—This destroyer, of 350 tons displacement, has made a very interesting series of trials. The data of these trials is given below:

Boiler pressure.	I.H.P.	Speed, knots.
180 pounds,	1,158	18.3
180 pounds,	1,444	19.3
200 pounds,	2,994	24.7
200 pounds,	3,350	25.6
200 pounds,	3,850	26.6
200 pounds,	4,907	27.2
200 pounds,	1,966	20.8
200 pounds,	2,123	22.3
220 pounds,	5,350	30.038
220 pounds,	5,724	30.558
200 pounds,	5,278	30.2

The trials were brought to a close by a coal-consumption trial, six hours natural draft, during which a mean power of 3,314 I.H.P. was developed, with a consumption of 1.95 pounds per H.P. per hour, and 76.7 pounds per square foot of grate surface.

New Destroyers.—Four new destroyers of the *Nembo* type, 350 tons, are to be built for the Italian Navy by Pattison, of Naples.

THREE HOURS' OFFICIAL TRIAL, NOVEMBER 21, 1901.

Run.	Hour.	Boiler steam.	First intermediate receiver.	Second intermediate receiver.	Vacuum.	Air pressure in stokehold.	Revolutions per minute.	Time.	Speed.	First mean.	Second mean.	Admiralty mean.
	A. M.	*lbs.*	*lbs.*	*lbs.*	*in.*	*in.*		*m. s.*				
1	11·8	229	64	12.5	22.3	1.5	407	1 51	32.432	30.779	31.067	31.300 knots per hour on measured mile.
2	11·18	229	63	12.5	22.3	1.6	401.4	2 3.6	29.126	31.354	31.450	
3	11·28	233	66	14.0	22	1.7	414.2	1 47.2	33.582	31.545	31.368	
4	11·38	236	66	13.9	21.5	1.3	403.5	2 2	29.508	31.192	31.315	
5	11·47	232	65	13.4	21.3	1.3	408.5	1 49.5	32.876	31.438		
6	11·57	240	65	13.7	20.8	1.1	403.5	2 ...	30.000			
Mean.	On miles.	233	65	13.3	21.7	1.4	406.35	.....	.....	.....	.....	.....

Means for the three hours' trial: 230 pounds of steam; 64 pounds in first intermediate receiver; 13 pounds in second intermediate receiver; 20.3 inches vacuum; air pressure in stokeholds, 1.3 inches; mean revolutions per minute, 404; mean speed during three hours, 31.121 knots; I.H.P., 6,450; coal consumption on the three hours' continuous run, 1.97 pounds per H.P.

Turbine.—This destroyer was launched at Naples on November 21, 1901. Her principal characteristics are as follows: Length, 209.9 feet; beam, 19.52 feet; draught (greatest), 7.51 feet; displacement, 350 tons. Her hull, of galvanized steel, is divided into seventeen watertight compartments. Two 4-cylinder triple-expansion engines, steam for which will be furnished by three water-tube boilers, are to develop 6,000 H.P. and give a speed of 30 knots. The coal supply will be 80 tons.

JAPAN.

Akatsuki.—The following particulars of the trial trip of a Japanese destroyer will be read with interest, as she deserves to rank with the fastest craft afloat, her speed having been considerably exceeded only by the ill-fated turbine destroyers, and by two or three others which have attained a fraction of a knot more on the measured mile. The destroyer in question is the *Akatsuki*, built for the Japenese Government by Yarrow & Co., Poplar.

The contract was signed November 5, 1900. She was launched November 13, 1901, and the preliminary trial took place November 14, 1901.

Load carried, 40 tons. Runs on the Maplin mile. Weather, wet; fresh breeze; sea, moderate. Left yard at Poplar, 8·45 A. M.; arrived Gravesend, 10 A. M.; left Gravesend, 10·11 A. M.; returned to Poplar at 5·20 P. M. Her three hours' official trial is given on page 342.

Asashio.—Messrs. John I. Thornycroft and Co. (Limited), of Chiswick, have launched the 31-knot torpedo-boat destroyer *Asashio*, building for the Japanese Government.

Kasumi.—The following data of the trial of the Japanese destroyer *Kasumi*, built by Yarrow Co., Poplar, England, have been furnished the JOURNAL by the builders:

Launched, Thursday, January 23d; preliminary trial, Friday, January 24th; official trial, Wednesday, January 29th.

The official trial consisted of a three-hours' continuous run with a load of forty tons on board; the speed being ascertained by six runs at the Maplin measured mile. The following is a record of the six measured-mile runs:

Run.	Hour.	Air pressure in stokehold.	Revolutions per minute.	Time.	Speed.	First mean.	Second mean.	Admiralty mean.
	A. M.	*inches.*		*min. sec.*				
1	11·13	.6	395.8	2 40	29.032			
2	11·24	.93	392.1	1 49.4	32.906	30.969	30.882	
3	11·33	.9	390.3	2 5.5	28.685	30.795	30.941	31.075 knots on measured mile.
4	11·43	1.1	396.8	1 47.5	33.488	31.087	31.161	
5	11·54	1.1	398.1	2 4.2	28.985	31.236	31.315	
6	12·3	1.2	401.7	1 46.5	33.802	31.394		

After the six runs were made, to ascertain the advance per revolution of the screw a three-hours' trial was proceeded with, with the result that a mean speed during the three hours of 31.245 knots was obtained.

Mikasa.—"The finest battleship in the world," is the enthusiastic verdict passed by the majority of those who have visited the *Mikasa* during her stay at Portsmouth. Being the latest, this, of course, is as she should be, but there seems a general feeling amongst naval officers that she embodies as great an advance in internal arrangements, and so forth, as in the more obvious and widely-known disposition of her artillery. Of this, however, presently.

The *Mikasa* is the fourth of four battleships—*Shikishima*, *Asahi*, *Hatsuse* and *Mikasa*—constructed for the Imperial Japanese Navy. The other vessels have been fully described in our columns in the past. It suffices here to mention that all four are of about 15,000 tons displacement, and resemble each other sufficiently closely for the first three—which carry the secondary guns in casemates—to be regarded as sisters. The *Mikasa*, having her secondary guns in a battery, only belongs very generally to the same class as her predecessors.

Her displacement is 15,200 tons; length between perpendicu-

Leading Particulars of Japanese Battleships Built in Great Britain, 1894–1901.

Dimensions, &c.	*Fuji.*	*Yashima.*	*Shikishima.*	*Hatsuse.*	*Asahi.*	*Mikasa.*
Builders of ship	Thames Iron Works,	Sir W. G. Armstrong & Co.	Thames Iron Works.	Sir W. G. Armstrong & Co.	Clydebank.	Vickers, Sons and Maxim.
Makers of engines	Humphrys & Tennant,	Humphrys & Tennant,	Humphrys & Tennant.	Humphrys & Tennant.	Ditto.	Ditto.
Date when laid down	1894	1894	1898	1899	1899	1899
Length bet. perpendiculars	374 ft.	372 ft.	400 ft.	400 ft.	400 ft.	400 ft.
Breadth	73 ft.	73 ft. 6 in.	75 ft. 6 in.	76 ft. 6 in.	75 ft.	76 ft.
Draught (mean)	26 ft. 6 in.	26 ft. 3 in.	27 ft. 3 in.	27 ft.	27 ft. 3 in.	27 ft. 2 in.
Displacement, in tons	12,450	12,330	14,850	14,900	15,200	15,200
I.H.P. (designed)	13,500	13,500	14,500	14,500	15,000	15,000
Speed in knots (designed)	18½	18½	18	18	18	18
Armament	Four 12-in. breech-loading guns, twin-mounted in barbettes on the middle line, at the extremities of the ship. Ten 6-in. quick-firing guns, four in casemates and main deck and six in ordinary shields on upper deck. Twenty 3-pounder quick-firing guns. Four 2½-pounder quick-firing guns Five torpedo tubes—four submerged.		Four 12-in. breech-loading guns, twin-mounted in barbettes on the middle line at the extremities of the ship. Fourteen 6-in. quick-firing guns in casemates—six on the upper deck and eight on the main deck. Twenty 12-pounder quick-firing guns, four firing ahead and four astern. Eight 3-pounder ditto. Four 2½-pounder ditto. Four submerged torpedo tubes—two forward and two aft—one above-water tube fitted in *Shikishima* only.			Same armament as in the three preceding vessels, but with a new system of protection for the 6-in. guns, four being in casemates on the upper deck and ten on the main deck, in concentrated casemates within the armored citadel.
Armor	Partial belt, 18 in., 16 in. and 14 in. Armored citadel from top of belt armor to main deck, 4 in. thick. Screen bulkheads, 4 in. Barbettes for 12-in guns, 14 in., 9 in. and 5 in. Casemates for 6-in. guns, 6 in. and 2 in. Conning tower, 14 in. Protective deck, 2½ in.		Complete water-line belt, varying in thickness from 9 in. amidships to 7 in., 5½ in. and 4 in. at ends. Armored citadel from top of belt armor to main deck, 250 ft. in length and 6 in. thick. Screen bulkheads at ends of citadel, 6 in. Barbettes for 12-in breech-loading guns, 14 in. thick. Water-line bulkheads in way of barbettes, 12 in. Casemates for 6-in. guns, 6-in. fronts and 2-in. rears. Conning tower, 14 in. thick. Protective deck, from stem to stern, 2 in. thick, increased to 3½ in. on slopes within citadel—all mild steel.			Complete belt of the same thickness as in the three preceding ships. Armored citadel of the same length and thickness as in the sister ships, but carried to upper in lieu of main deck, and forming protection for ten of the 6-in. guns. Remainder of armor as in the three preceding ships. Protective deck, from stem to stern, 2 in. thick, increased to 3 in. on slopes within citadel, with an added thickness of 1½ in. of nickel-steel over exceptionally vital parts.
Machinery.						
Type	Vertical, triple-expansion, three-cylinder engines, with twin screws in each vessel.					
I.H.P.	13,500		14,500		15,000	15,000
Cylinders	40 in., 59 in. and 88 in.		34 in., 53 in. and 84 in.		32½ in., 52 in. and 85 in.	31 in., 50 in. and 82 in.
Stroke of pistons	45 in.		48 in.		48 in.	48 in.
Revolutions per minute	120		120		108½	120
Number and type of boilers	Ten single-ended cylindrical.		25 Belleville.		25 Belleville.	25 Belleville.
Heating surface	21,000 sq. ft.		39,760 sq. ft.		...	37,452 sq. ft.
Grate area	820 sq. ft.		1,142 sq. ft.		...	1,276 sq. ft.
Coal, at designed draught	700 tons.		700 tons.		700 tons.	1,000 tons.
with bunkers full	1,200 tons.		1,800 tons.		1,800 tons.	2,000 tons.

—"London Engineering."

lars, 400 feet; length over all, 436 feet; beam, 76 feet; draught, 27 feet 3 inches, on an even keel.

The armor is disposed as follows: On the belt amidships there is 9-inch to 7-inch of Krupp cemented armor, extending about two-thirds of the ship's length, the amidships section of 156 feet being the full thickness, while the 7-inch armor has an extra 1½-inch on the armor deck that reinforces it. There are 12-inch transverse bulkheads, after which the belt proceeds at a thickness of 4 inches to the bow and nearly to the stern, where another bulkhead, 6 inches thick, protects it. This main belt is 7 feet 9 inches wide, and 5¼ feet are intended to be below water. Behind this belt is the usual armor deck, 4 inches thick on the slopes, reduced to 3 inches amidships and 2½ inches on the flat. Along the lower deck, for the same distance as the main belt, is a 6-inch belt, terminated, like the main belt below, with bulkheads that join the barbette bases. These are 14 inches to 10 inches thick. The hoods that surmount them are 10 inches in front, 8 inches at the sides. In form they are loftier and more rectangular than in British warships; they also appear somewhat smaller. The barbette rises a good 6 feet or more above the upper deck, so that the heavy guns are carried some feet higher than in our battleships.

On the main deck is the feature of the ship—the battery. Here, amidships, are ten 6-inch guns, five a side, the foremost and aftermost in sponsons, the amidship ones with ports flush with the side of the ship, their sides indented to admit of an increased angle of fire. This is American fashion. It has been unfavorably criticised on the grounds that such indentations form a species of nest in which shells bursting are absolutely certain to disable the gun. This is absolutely true; but there is the other side of the question, as there always is to these things. A shell so lodged is more likely to expend itself locally, and that is the great desideratum of defence. In addition, the area of the opening is small, and so a good deal of smooth armored wall is presented. The *Mikasa* system of a compact slightly indented port is therefore probably preferable as a whole to the slightly sponsoned battery ports of the Italian designs with these

continuous batteries, and to the American system in which—to increase the angle of fire and for convenience of housing guns—the size of the ports is considerably greater. The *Mikasa's* battery is 6 inches thick. Bulkheads terminate its ends, and in the rear of the guns runs a 2-inch lateral bulkhead. From this to the sides run 2-inch screens, so that the sum total of effect is a number of casemates placed together instead of with intervening gaps.

Here we have the problem of battery *versus* casemate. A battery of this sort is at the mercy of a big armor-piercing projectile in a fashion in which no series of casemates can ever be; but, on the other hand, the gaps between casemates admit small projectiles to wreak havoc 'tween decks and to interrupt communications. This last is an acute point that does not show on paper. Transmitters, of course, exist in plenty, but they do not find a place on board our ships, where faith is put in loud-speaking telephones that no one expects to hear on the day of battle. In battle the odds are greatly that all orders will go by messenger, and how the messenger is to traverse the shell-swept gaps between casemates is a considerable problem, to be solved only by armoring the messengers, which no one has yet suggested. The other alternative is to keep out the shell, as is done in the *Mikasa.*

Four 6-inch guns are carried on the upper deck, in casemates, so placed that their bases are well inside the battery armor. These casemates are 6 inches thick, and, like all the armor in the ship, of Krupp cemented steel, not Harvey nickel, as in most other ships built or building. To the great difficulty in making these cemented casemates a good deal of the delay of the ship is attributed. The armament, of Elswick make, is as follows: Four 12-inch 40-caliber rapid-loading guns, fourteen 6-inch 40-caliber quick-fire guns, twenty 3-inch quick-fire 12-pounders, eight 3-pounders, four in each fighting top; four 2½-pounders, Japanese type, on top sides; four 18-inch new Elswick patent submerged tubes.

Eight of the 12-pounders are disposed in the battery on the upper deck amidships, four surmount the casemates, four are

around the conning towers, two on the main deck in the bow, two on the same deck aft. The 3-pounders are in the fighting tops. For those who like such calculations, we may mention that the "total weight of metal discharged by the guns in one minute is 11.5 tons. From one broadside it is 7.5 tons. The respective energies of fire in one minute are, 1,337,130 foot-tons and 1,000,000 foot-tons." But these figures have no particular practical meaning, of course, besides being rather too suggestive of diagrammatic articles in " popular" magazines. The sailor's problem is not to tot up the energy at disposal, but to expend it on the enemy. Otherwise, on the liberal computation that it takes a man's weight in metal to kill him, there is always the risk of a new genius arriving who shall thus compare battleships. This would give the *Mikasa* a killing power of about 110 men per minute. Practically her fire is much the same as that of any other first-class ship. Far more important than these theoretical energies are the arcs of fire. These, for the amidship 6-inch, are 60 degrees before and abaft the beam; for the sponsons, 80 degrees before or abaft, and 40 degrees abaft or before. The casemates have 118 degrees from the axial line. The big guns have 240 degree arcs of fire.

The engines are two sets, three cylinders, triple-expansion, the diameters of the cylinders being 31 inches, 50 inches and 82 inches. The stroke is 48 inches. Full power is 15,000 indicated horsepower, which, with 120 revolutions, is to give 18 knots; pressure at boilers, 300 pounds, reduced to 250 pounds at the engines. Stephenson link motion is adopted for working the valves, which are piston type, on the high-pressure and intermediate cylinders, and of the double-ported flat design, on the low-pressure cylinders. The screws are inward turning, as in our new battleships. The starting platform is in the center of the ship. Wrought-steel columns form the front supports of the cylinders, which are independent castings. The back supports are the ordinary cast-iron Λ framing, with ample slipper-guide surface. The condensers are separate, and placed in the wings.

The total cooling surface is 16,014 square feet.

The bed plate is cast steel. The crank shaft is of nickel-steel.

External diameter, 16½ inches, with an 8¼-inch hole. The propeller shaft is wrought steel, 16½ inches in diameter, with 8¼-inch hole. The propellers, four-bladed, have a diameter of 17 feet; pitch, 18 feet. The blades and boss are manganese-bronze.

The boilers are Belleville, disposed differently from the usual practice. The first funnel serves five and ten boilers, the after funnel serves ten—thus reversing the usual practice. These funnels are very large, and the fore one is much further from the mast than in the *Asahi*—the other two-funneled ship. Further particulars of the boilers are as follows: Twenty consist of eight elements of generating tubes and seven elements of economizer tubes, while the remaining five have seven elements of generators and six of economizers. The total heating surface is 37,452 square feet; the grate area, 1,276 square feet. All told, the machinery weighs 1,355 tons.

The coal capacity is 1,400 tons, which gives a nominal radius of 9,000 knots at 10 knots. There are six search lights, and the lighting installation comprises 900 icandescent lamps. There are electric hoists to all guns.

In accordance with the new Japanese custom, the *Mikasa* is painted black, with black funnels, gray masts and upper works. There are white bands upon the funnels to distinguish her from other two-funneled ships. The *Fuji* has none, *Yashima* one, *Asahi* two and *Mikasa* three on each funnel. She is, however, easily recognized from the *Asahi* by the different positions of her funnels, their greater size, the high fore barbette turret, and rather less sheer forward.

In accommodation the *Mikasa* is excellent, and gives immense satisfaction. The ward room is on the main deck instead of the lower deck, as in the other three ships. It is on the port side just abaft and around the barbette, with a fine passage outside leading to the captain's and admiral's quarters. All the fittings are very sumptuous, the electro-silver electric-light clusters being of a particularly pleasing design. This attention to minor details is carried out very consistently throughout the entire ship, and though of minor import for a warship, should make the builders formidable rivals if they enter the field of liner con-

struction. There is about all these things an artistic reticence reflecting immense credit on all concerned.

As the battery *versus* casemate question is now so much upon the tapis, our readers may be interested in the following lists, showing how far the rival systems are adopted. An asterisk (*) indicates ships not yet completed.

Nation.	Casemates (or turrets).	Battery.
British,	3 *Londons*,	3 *King Edwards.**
	2 *Queens.**	2 *Trafalgars.*
	6 *Duncans.**	
	3 *Formidables.*	
	6 *Canopus.*	
	9 *Majestics.*	
	7 *Royal Sovereigns.*	
	Hood.	
French,	4 *Bouvet* type,	*Suffren.*
	Jaureguiberry,	*Iéna.*
	2 *Republiques,**	3 *Charlemagnes.*
		*Henry IV.**
		Brennus.
German,	5 *Kaisers*,	5 *Wittelsbach.**
		2 *H* and *J.**
		4 *Brandenburgs.*
Russian,	6 *Borodinos,**	*Retvisan.*
	2 *Peresviets.*	*K. Potemkin Tavritchesky.*
	Pobieda,	*Tri Svittitelia.*
	3 *Poltavas*,	*Sissoi Veliky.*
	Postislav,	*Navarin.*
		Dvenadsat Apostoloff.
U. S. A.,	*Iowa*,	5 new ships.*
	3 *Indianas*,	3 *Maines.**
		3 *Alabamas.*
		3 *Kearsarges.*
Japanese,	3 *Shikishimas*,	*Mikasa.*
	2 *Fujis.*	
Italian,	2 *Vittorio Emanueles,**	2 *Brin.**
		2 *Filibertos.*

Which gives seventy-one ships with casemates or turrets for secondary guns, of which eighteen are yet building, while batteries are adopted in forty-seven ships, of which twenty-one are yet building. This makes the figures for new ships nearly equal, but exhibits a decided growth of the battery idea. The notion, of course, is as old almost as ships are. The earliest ironclads embodied it and abandoned it only when guns grew too big to carry on the broadside. If in Nelson's day the battery was broadside because it could be nothing else, this cannot apply to earlier wooden walls in which the battle was fought. War always indicated the necessity of being able to control fire, and to do so propinquity of guns was found essential. It is likely to happen again. Despite certain advantages of the casemate system, there is all too much reason to doubt how it is going to answer in war, when the problem of communications on board will be as important as it is to an army in the field. In peace time, in the midst of such arduous duties as keeping ships nicely painted, seeing that men's collars are of the regulation size, and hunting for dirt marks in dark corners, the question of fire control in action stands, of course, to get shelved; but in war it will assert itself, and may prove quite as important as the details referred to above. And a battery *a la Mikasa* seems the simplest solution. The *Mikasa* was laid down at Barrow in 1899, and launched on November 9th, 1900.—"Engineer."

The following report of the trial of this vessel is taken from "London Engineering:"

Turning now to the latest ship, the *Mikasa*, most successful results have been achieved, alike in speed, coal consumption, maneuvering, and in gun power. The first trial of interest was that to determine the coal consumption, and here the contract, as with all Japanese ships, required the vessel to be run for six hours at four-fifths of her full power, during which the mean coal consumption was not to exceed 2 pounds per unit of power per hour. On this, as on all trials, the vessel was at her full-load draught, and, having all her guns in position, was practically ready for action. The mean power on this run was 12,325 indicated horsepower, the half-hourly indicator diagrams showing

that the variations were confined between 12,000 and 13,000; the mean revolutions of the engines were 112. The boilers of the Belleville type, 25 in number, were worked entirely by Japanese stokers, and the mean consumption worked out at 1.53 pounds per indicated horsepower per hour. This result has only been equalled within the past two years by one British battleship—namely, H. M. S. *Vengeance*—which also was built by Messrs. Vickers, Sons, and Maxim, and the coal consumption of which on her official thirty-hours' trial at three-quarter power was 1.51 pounds per indicated horsepower per hour. The speed on this trial of the *Mikasa* was 17.36 knots. Progressive speed trials were made at the lower powers on the measured mile at Stokes Bay, and at the higher powers on a deep-sea 10-mile course off the coast of Devon, and we tabulate the results as follow:

PROGRESSIVE RESULTS OF THE "MIKASA."

At 10	knots,	. .	2,000	indicated	horsepower.
12	"	. .	3,450	"	"
14	"	. .	5,500	"	"
16	"	. .	8,500	"	"
18.54	"	. .	16,400	"	"

The aim of the trial was, of course, to approximate, as closely as possible, certain pre-determined rates of speed. On the deep-sea course the weather conditions were, unfortunately, not conducive to satisfactory steering, as a haze prevented the navigator observing the buoys, and, consequently, he had to depend entirely upon the compass for making a straight course. The observation of the wake of the ship made it quite clear that the ship travelled a much longer distance than the course bearings indicated. This was clearly established when the vessel went on her full-speed run, also on a deep-sea course, for, without increase of power or revolutions, the mean speed obtained was 18.54 knots; but here again the same weather conditions affected the steering, although in a slightly less degree, so that the Japanese staff on board were satisfied that this rate does not even represent the full possibility of the ship. This speed of

18.54 knots was got with a mean of 16,432 indicated horsepower—the contract requirements were 18 knots and 15,000 indicated horsepower—and it is a noteworthy point that on one of the runs the mean revolutions of both engines were exactly the same, while in another case the variation was within one revolution.

On all the trials the ship was run on an even keel, and in this respect the conditions differ from those obtaining at British naval trials, their practice being usually to trim the ship by the stern, which, of course, greatly assists the steering and maneuvering; but under this condition the *Mikasa* proved a quick maneuvering ship, and thus her circling trials were watched with great interest. These were carried out, according to practice, at 17 knots; and to determine the diameter of the circle, Barr and Stroud's ingenious and accurate range finder was brought into use. The ship was first turned to the starboard with the helm, of course, hard over, the engines making a mean of 88¾ revolutions; the action of the helm gave a variation of 3½ revolutions, the port running free at 90½ and the starboard, with the helm against it, at 87 revolutions. The diameter of the circle described was 1,300 feet, the time taken being 4 minutes 10 seconds. Immediately the circle was turned, the rudder was thrown right over to hard-a-port, and the circle in this case was smaller, the diameter being 1,225 feet, although the time taken was 10 seconds more, the revolutions of the starboard engine being 87, and of the port 88, giving a mean of 87½. The time taken to put the helm full over from hard-a-starboard to hard-a-port by the steam gear was 55⅝ seconds, and the reverse action occupied practically the same time—56 seconds. Engine stopping and reversing trials were also carried out and gave equally satisfactory results.

All the guns in the ship were tried, and the results were consistent with the satisfactory nature of those attained by the engines and the ship itself. Two rounds were fired from each of the fourteen 6-inch guns and from the thirty-two smaller weapons, while from the submerged torpedo tubes ten rounds were fired—six when the vessel was steaming at speeds varying from 15 to

17 knots, and the others when she was anchored in Tor Bay. The two 12-inch guns mounted in the after barbette were tested for rapidity of fire rather than for accuracy of aim, three-quarter charges and full charges being used in the several rounds, the best result from the order to load until the gun was fired being 30 seconds, while other rounds similarly timed took 39 and 40 seconds. Both guns were fired simultaneously with three-quarter charge and with full charge, a severe test upon the structure of the ship, but a subsequent careful examination proved that the only effect was the loosening of one or two bolts, and the breaking of one or two glasses. The two forward 12-inch guns were tested by three rounds being fired successively from each gun at a range of 1,800 yards, to determine the aim as well as the rapidity of fire, and the first three rounds were fired from one of the guns in 143 seconds, which gives the satisfactory average of 48 seconds per round, the time including delays owing to the hydraulic rammers being locked and to the haze obscuring the target for a short period. The first shot lifted the target out of the water, the second was from 10 to 20 yards over, and the third 10 yards to the left and 20 over. Three shots from the other guns were also satisfactorily fired.

Niitaka and Tsushima, New Cruisers.—The special interest of these vessels lies, of course, in the fact that they are absolutely Japanese. Mr. Satow, the Japanese chief constructor, designed them; Japanese workmen at Kure and Yokosuka are building them; Japanese factories have designed and made all their material, armor, machinery, ammunition and guns. In this an epoch is marked.

The first warship of any account built in Japan was the *Hashidate*, of 4,277 tons, but she was merely put together. She was sent out in pieces and erected under French supervision. This ship was followed by the *Akitsushima*, of 3,150 tons, a reduced copy of the American *Baltimore*. Whether she should be considered American* or Japanese in design is, perhaps, a moot point. In any case, she is no credit to any one, her steaming qualities being indifferent and her seaworthiness by no means

* Editorial note.—The *Baltimore* is an English design.

beyond question. Her engines were made in Japan, but from Western designs.

In 1893–94 the *Suma* was designed, her sister, the *Akashi*, following somewhat later. These ships were entirely designed in Japan, and are currently supposed to be purely Japanese in material. This is partly quite true, partly quite incorrect. There is reason to think that the "stand-by" Westerner has been the *deus ex machina*. She is practically the famous *Yoshino* with 50 feet of her length cut out abaft the funnels, and though none of the material was imported, some of the designs for it were. Of the ships under review this can hardly be said—they are essentially Japanese, though the inspiration for the design may still be found in the Elswick *Yoshino* or *Takasago*, which are practically sisters.

Below we give data of the *Niitaka* class, compared with (1) the Japanese cruisers of Japanese design; (2) the Elswick cruisers alluded to above; (3) the three foreign designs nearest to them in size. Direct comparison is impossible, for there are no modern 3,400-ton ships. The French vessel is much larger, the German much smaller, while the American one is out of court on the score of speed. With regard to the American *Denvers* or *Chattanooga* class a few words may be said. Probably they will do 19 knots, or near it, but they will do so only because of the patriotism of American builders. The whole position is extraordinary. As once in this country, so in America, the authorities have, it would seem, been attacked with the mania for building ships that under no conceivable circumstance can have any war use, except as coffins for sailors. In peace they swell the list of effective vessels, and do duties that could be discharged equally well by the scores of obsolete craft lying idle in the dockyards. In sober fact they are "political" ships—a very ignorant voter may give his vote to the party that laid down "such a lot of new warships." The British public is more gullible than the American, presumably, since our "twin-screw" sloops carry the veriest pop guns in armament, have no speed, and, indeed, nothing to boast of save the "twin screws."

The American "humbug ships"—to quote a famous naval

officer—have, besides twin screws, an imposing armament and a pretense at protection. Even so, the Navy Department, after ordering them, seem assailed with doubts, and they then imported method into their madness. With an acumen, excellent for everybody save the unfortunate contractors, they let it be known that America expected that the patriotism of the builders would see to it that the contract speed and horsepower were heavily exceeded—without extra cost to the American nation—which is nice for America, but hard on the builders as we have said.* However, be all this as it may, it is not fair, for the reasons mentioned, to compare the American cruisers with the Japanese.

The diversity of armament is so great that we have commuted all guns of 3-inch, 12-pounders and over to the value of 6-inch pieces, on the assumption that in shell fire—which is the only thing cruisers are concerned with—an 8-inch quick firer equals 1½ of 6-inch quick firers, and that this piece is equal to two 4.7's, 1½ of 5-inch, three 4-inch or four 3-inch. This is approximately accurate practically, though it may not always fall in with "weight of metal discharged in one minute" calculations and statistics. The drafts given are maxima, and in the machinery the engines are three cylinder, unless otherwise stated.

From this table it will be noticed that in the matter of armament per ton of displacement, the Japanese vessel is practically on a par with Elswick designs. The fact that the German ship is only half as heavily armed is worthy of note. Evidently in these cruisers the German ideal is something seaworthy, a scouting ship, in fine—and armament is also sacrificed to speed. Reverting to the Elswick vessels, it will be noted that while the 3,400 and the 4,300-ton ships carry proportionately equal armaments, the larger vessels have an abnormal advantage in their thicker decks; and this incidentally leads us to a subject another aspect of which we have considered upon a previous occasion, namely, what size is best value for the money. This, we think, Elswick solved in the *Takasago*, in which the increased size gives a better deck and more speed. If we go above 4,000 odd, and take a

*Editorial note.—There is no doubt that this remarkable statement will be news to all Americans.

.....	*Niitaka* and *Tsushima.*	*Suma* and *Akashi.*	*Akitsushima.*	*Takasago.*	*Protet.*	*G. H.* and *J.*	*Denvers.*	*Yoshino.*	*Novik.*
Date.	(1902)	(1895–'97)	(1892)	(1897)	(1897)	(1902–'3)	(1901–'2)	(1892)	(1901)
Nationality	Japan	Japan	Japan	Japan	France	German	U. S. A.	Japan	Russia.
Displacement, tons	3,420	2,700	3,150	4,300	4,065	2,715	3,200	4,150	3,000
Length, feet	334½	305	302	360 (p. p.)	332	360	292	350	361
Beam, feet	44	41	43	46½	44½	40½	44	46½	39½
Draught, feet	16½	16½	18½	20	21½	17½	17½	20	19
Armament.	Six 6-in. Ten 3-in. Four 2½-pdr.	Two 6-in. Six 4.7-in. Twelve 3-pdr Four machine	Four 6-in. Six 4.7-in. Ten 3-pdr.	Two 8-in Ten 4.7-in. Twelve 3-in. Six 2½-pdr.	Four 6.4-in Ten 4-in. Ten 3-pdr.	Ten 4-in. Ten 1-pdr. Four machine	Ten 5-in. Eight 6-pdr. Two 1-pdr. Two Colts.	Six 6-in. Eight 4.7-in. Twenty-two 3-pdr.	Six 4.7-in. Eight 3-pdr.
Value of guns commuted to 6-in	8½	5	7	11	7½	3½	6⅔	10	3
Torpedo, submerged	None	None	None	None	None	2	None	None	None.
Torpedo, above water	None	2	4	5	2	None	None	5	5
Armor deck	2½-in	2-in	3-in	4½-in	2-in	2-in	2-in (partial)	4½-in	2-in.
Engines	Triple exp., vertical.	Triple exp., vertical.	Triple exp., vertical.	Triple exp., vertical.	Triple exp., horizontal.	Four cylin., triple exp.	Four cylin., triple exp.	Triple exp., vertical.	Triple exp.
Screws	2	2	2	2	2	2	2	2	3
I.H.P., full power	9,500	8,500	8,400	15,000	9,500	8,000	4,500	15,000	17,000
Full speed	20 knots	20 knots	19 knots	24 knots	19.6 knots	22 knots	16½ knots	23.08 knots	25 knots.
Normal coal, tons		200	500	300	550		467	300	...
Maximum coal, tons	600	600		1,000	600	700	700	1,000	...
Boilers	Niclausse	Cylindrical	Cylindrical	Cylindrical	Belleville	Schulz	B. & W.	Cylindrical	Thornycroft.
Approximate number of tons of displ. per 6-in. gun or equivalent.	400	540	450	390	570	868	500	415	1,000

ship like the *Variag*, of 6,500 tons, we find her "gun units" 15, which works out at a 6-inch gun or equivalent for every 430 tons displacement. She has no more speed, but rather less, and if she carries more coal there is a 3-inch instead of a 4½-inch deck against it.

As for the 3,400-ton ships and thereabouts, they are really 2,000 tonners writ large. We in the *Pelorus* class, Germany in the *Gazelle* class, and, no doubt, Japan in the *Suma*, have all made the same discovery, that there is no place in warfare for ships over 8,000 tons or so, and under 3,000 tons. The ships of 2,000 tons odd are cheap to build, but there their utility ends. They soon shake themselves to pieces with rough usage and their fighting value is small. Hence the German increase to 2,715, Russia's adoption of a 3,000 ton *Novik*, Japan's advance to 3,420 tons, and our—also France's—discarding of anything between 500 and 5,000 tons. Belated wisdom on our part it may be, but undoubtedly it is wisdom. There is small chance of the *Novik's* being successful finally, according to the latest accounts of her trials, while her gun units come to only 1 per thousand tons of displacement. The sacrifice made in her is fearful. The *Takasago* has two and a half times her gun fire, double her armor deck, and only a knot less speed—while in practice she is probably faster. The German ship is slower, of less than half the *Takasago's* value in fire per ton of displacement, while the Japanese type sacrifice speed for gun power.

All told, it is hard to make out a case for these medium-sized vessels. As far as they go, Japan has probably struck the best mean, but that is all. However, as we have said, the principal interest in the Japanese type is that it represents the arrival of Japan as a shipbuilding power.—"Engineer."

Shirakumo (White Cloud).—This torpedo-boat destroyer which is the first of two vessels now being completed by Messrs. John I. Thornycroft & Co., Limited, for the Imperial Japanese Government, has undergone a successful full-speed trial in very boisterous weather, at the mouth of the Thames. In spite of the unfavorable conditions, the mean speed maintained during the three-hours' trial was 31.030 knots. The results of six runs

over the measured mile at the Maplin Sands were as follows, the conditions as to loading, &c., being very similar to those for British Admiralty vessels of this class:

Run.	Time.	Speed.	Mean revolutions.	Steam pressure.
	min. *sec.*	*knots.*	*per minute.*	*lbs. per sq. in.*
1	1 50.8	32.491	394.0	222
2	1 58.6	30.354	394.9	227
3*	1 48.4	33.210	407.4	230
4*	1 56.8	30.822	398.5	235
5	1 49.0	33.027	406.5	235
6	1 58.6	30.354	390.5	235

* True mean speed, 31.819 knots. True mean revolutions, 400.8 per minute.

It will be seen that the mean of runs 3 and 4 is over 32 knots, so that the *Shirakumo* is one of the fastest vessels in existence. The vessel proved a good sea boat, and noticeably free from vibration. The *Shirakumo* and her sister vessel, the *Asashio*, are 216 feet in length, about 21 feet beam and have a maximum draught of about 8 feet 6 inches. They carry the armament usual in vessels of this class.

PORTUGAL.

Tejo.—This gunboat was launched on October 27, at Lisbon. The principal dimensions are as follows: Length over all, 22 feet 22 inches; Length between perpendiculars, 22 feet 22 inches; maximum beam, 22 feet 22 inches; beam at water line, 22 feet 22 inches; draught, 22 feet 22 inches; displacement, 532 tons; boilers, type, Sigaudy; engines, triple-expansion; horsepower, 7,000; designed speed, 25 knots. The hull is of nickel-steel.

RUSSIA.

Kniaz Potemkin Tavritchesky, Russian Battleship.—The *Kniaz Potemkin Tavritchesky* is nominally a sister to the *Tri Svititelia*, and as such, save for an increased armament and reduced armor thickness, she was commenced. The low freeboard of the *Tri Svititelia*—which is practically a copy of the British *Trafalgar*—has, however, been held against that ship, and the latter vessel is built up forward. As designed she was to have been a *Tri Svititelia*, with four turrets carrying pairs of

6-inch guns where the older vessel carries single 4.7's in recessed ports; but the raising of the forecastle enabled a longer main-deck battery to be employed, and so she is, saving for the continuous battery armor, not unlike the British *Majestic* cut away aft, so far as disposition of guns is concerned. Whether this is better than the previous adoption of the *Poltava* idea remains to be seen. Compared with the *Tri Svititelia*, the particulars of the *Kniaz Potemkin Tavritchesky* are as follows:

	K. P. Tavritchesky.	*Tri Svititelia.*
Displacement, tons	12,500	12,500
Length, feet	370½	371
Beam, feet	73	72½
Draught (mean), feet	27	27
Armament	Four 12.4-in., 40 cals.; sixteen 6-in., 45 cals.; fourteen 12-pdrs.; twenty 1-pdrs.	Four 12-in., eight 6-in., 45 cals.; four 4.7-in.; ten 3-pdrs.; forty small.
Armor, material	Krupp.	Creusot special.
belt	9-in.	16-in.
deck	4.3-in.	3-in.
Lower deck, side (redoubt)	6-in.	16-in.
Bulkheads	8-in.	12-in.
Turret	12-in.	16-in.
bases	10-in.	16-in.
Q. F. battery	5-in.	5-in.
Casemates	5-in.	Nil.
Conning tower	10-in.	12-in.
I.H.P.	10,600	10,600
Speed (nominal)	18 knots.	18 knots.
Boilers	24 Belleville.	Cylindrical.
Coal (normal)	670 tons.	750 tons.
Oil	600 tons.	Not known.
Coal (maximum)	870 tons.	1,000 tons.
Complement	600	582
Torpedo tubes, submerged	3	None.
above water	2 (armored).	6 (unarmored).

In the disposition of armor, that of the *Tri Svititelia* is generally followed in the *Kniaz Potemkin Tavritchesky*, save that for the flat deck of the former the latter has an inclined deck reinforcing the belt. It is the use of this deck which has enabled a good deal of thickness in the belt to be dispensed with, the total resistance to A. P. projectiles being about the same in both vessels.

The main belt is 7½ feet wide, and varies in thickness from 9 inches at the top to 5 inches at the bottom. At normal load draught 4½ feet of this belt are submerged. Its length is 250 feet, and at the ends are 8-inch bulkheads. The deck behind this belt is 4 inches thick—at the unprotected ends the thickness is reduced to 3 inches on the slopes. Its apex is some 3 feet above the normal water line.

Above the main belt is the lower deck belt, also 7½ feet high and 210 feet long, terminated by 6-inch bulkheads which connect with the turret bases, here 10 inches thick. A third main-deck belt tops the second belt. This battery belt has a length of about 185 feet, and is 5 inches in thickness. It is worked into angles that project for the 6-inch gun embrasures, the forward and aftermost gun port being recessed to allow of end-on fire. The forward ends of this battery belt are carried into the turret base, the after terminated by a flat 5-inch bulkhead. There are also 2-inch splinter screens isolating all the guns in this battery. Above the battery are four casemates, 5 inches thick, their bases protected by the battery.

The main turrets are elliptical in form, and balanced on bases that reduce in circumference as they descend. The thickness of the revolving turrets is 12 inches, the thickness of the bases 10 inches, till they reach the level of the 9-inch water-line belt and the protective deck. Thence they are carried to 4½ feet below the water line at a thickness of 5 inches, so that the protection here is 9 inches vertical, 4 inches inclined, and 5 inches circular. This may be summed up as equal to 9 inches + 9 inches + 6 inches = 24 inches of Krupp steel—equivalent, under the circumstances, to perhaps 4 feet of solid wrought iron, or twice as much as any gun in existence is likely to get through. Before the foremast and abaft the main are 10-inch conning towers, with 5-inch communicating tubes.

The big guns are "12-inch" pieces 40 calibers long, and some 64 tons in weight. The actual bore appears to be 12½ inches, and it is reported that these guns are being made by the Schneider-Canet firm, in which case they probably resemble the 12.5-inch guns supplied to certain Japanese cruisers. There is, how-

ever, always such a vail of mystery over Russian guns that it is impossible to give definite particulars. The quick-firing guns appear to be Obuchoff pattern, and are 45 calibers long. As the illustrations indicate, they are disposed four in upper-deck casemates and twelve in the main-deck battery. The 3-inch—12-pounders—are placed six on the upper deck, two at each end of the topside, two at the bow, and two at the stern. All are unprotected.

The submerged tubes embrace a bow one—here we see German influence—and two beam tubes placed just before the base of the fore turret. The above-water tubes are carried behind the 6-inch armor on the lower deck, just before the after turret and directly below the after conning tower.

The arc of fire of the big bow guns is 200 degrees only, while the after turret has an arc of 260 degrees. The upper deck and end main deck 6-inch have a 135 degree arc, the other 6-inch pieces 115 degrees. The amidships 12-pounders train 90 degrees, the topside ones 100 degrees, those at the ends 120 degrees.

Machinery data are as follows: Engines, two sets of vertical triple-expansion, with 10,600 indicated horsepower, and a speed of 18 knots. There are twenty-four Belleville boilers in three groups of eight. The three uptakes serving these are placed athwarthships instead of in the usual fashion. The 600 tons of liquid fuel are carried in forward and after bunkers below the protective deck, the 670 tons of coal are stowed amidships about the boilers. The 200-ton excess is to be stowed in the double bottom, and so will be very much of an emergency ration. Oil is the normal fuel for the furnaces, but their conversion to coal burners can be effected in about an hour.

All gun hoists are electric and hand, and the big guns are to be electrically maneuvered. It will be seen that the *Kniaz Potemkin Tavritchesky* is a very fair modern ship, able, so far as material goes, to hold her own against any other warship of the same date, while the extra quick-firers over the normal number give her a very formidable volume of fire from these pieces.

Reference may once more be made to the funnels of the *Kniaz*

Potempkin Tavritchesky. In the old days funnels were always put with the thin end of the oval facing the bow and stern, the idea being to offer the minimum of resistance to the wind. The first breaking of the rule was in the *Neptune*, in which—owing, it is said, to a misunderstanding—the funnels were put in with the larger surfaces fore and aft. Since then a single funnel was so put in the French *Trehouart*, but this, probably, is really a pair of funnels in one casing. In our *Canopus*, *Formidable*, *Duncan* and *London* classes, the big after funnel is also put in sideways, possibly with a view to symmetry on the broadside, possibly with the idea of offering a smaller target. The three almost rectangular funnels of the Russian ship under notice are so placed, partly to lessen the huge target they would otherwise present on the broadside, and partly to suit the arrangement of the boilers. As in all modern war vessels, these run athwartships instead of longitudinally as in the old days of "tanks," but it is said that the uptakes are divided between decks, and possibly carried all the way up in pairs in a single casing, so that, should a high-explosive shell burst inside the funnel, only one-sixth instead of one-third of the boilers may be affected. It is worthy of note that in Russia just now there is a good deal of theorizing about funnels, and the effect on them of battle. It is the only country in which the matter seems to receive any attention. We have, in previous issues, pointed out how the 'tween-deck uptakes in all new Russian cruisers are armored. From a simple belt to the funnel bases they now seem proceeding to an adoption of the same systems of isolation that are employed by all nations for gun protection and so forth.—"Engineer."

Boyarin.—The launch of this third-class cruiser took place recently at Copenhagen. Her length at the load-water line is 355 feet; extreme beam, 41 feet 6 inches; average draught, 16 feet; displacement, 3,200 tons. Her propelling power consists of two four-cylinder triple-expansion engines, each driving a separate screw. The whole power of the main and auxiliary engines is 11,500. The estimated speed is 22 knots. The boilers are of the Belleville type with economizers, sixteen in number, placed in three separate groups. The coal bunkers have a capacity,

when full, of 600 tons, which at a modified speed of 11 knots is sufficient for 5,000 miles. Her armament will be six 120-millimeter (4.7-inch) guns, eight 47-millimeter (3-pounder), two 37-millimeter boat guns, two Maxim small-bores, one Baranovski gun, and five under-water tubes for 18-inch Whitehead torpedoes, four on the broadside and one astern. She has an armored deck almost her whole length, and also to protect the vital parts, *i.e.*, the boiler and engine rooms and magazines, broadside and transversal cofferdams. The conning tower is also armored, and the various communications and ammunition hoists. Her crew will comprise 14 officers and 320 men.

Gagara.—This torpedo vessel, built by the Neva Engineering Works, has been on the measured mile to test her engines and speed. She has four boilers of a modified Yarrow type, and gave a speed of 27 knots, but was forced to put back into Kronstadt owing to a breakdown. The *Moskva*, one of the vessels accompanying her, is fitted with a Du Temple boiler, heated by naphtha, and is being closely watched by the representatives of the yard. The torpedo boats of the *Sokol* type built by the Ijora Works have, it should be noted, eight water-tube boilers.

Imperator Alexander III.—This battleship was launched August 3, 1901. Her principal dimensions are as follows: Length between perpendiculars, 376 feet 5 inches; extreme length with ram, 398 feet 1 inch; extreme beam with sheathing, 76 feet; draught on an even keel, 26 feet; displacement, 13,516 tons; I.H.P., 15,800; speed, 18 knots; full coal stowage, 1,250 tons. The engines intended for her are being constructed from original plans drawn up at the same yard, and are twin-screwed of the usual triple-expansion type. All the plans for the hull, engines, and Belleville boilers were worked out at the yard, and they and the turbines constructed there. The boilers are twenty in number, placed in two compartments, forming four stokeholds. The first plate of the keel was laid in September, 1899. She will be armed with four 12-inch, twelve 6-inch, twenty 75-millimeter (14-pounder), twenty-four 47-millimeter (3-pounder), and six 37-millimeter (1.7-pounder) guns, in all sixty-two in number, the 12- and 6-inch guns being carried in pairs in revolving tur-

rets. The armor is so distributed as to protect the armament and vital parts, there being two armored decks, and armored bulkheads. The hull is protected by a broad water-line belt of 9-inch Krupp armor tapering to 4 and 2.5 inches at the extremities; the turrets for the heavy guns are protected by 11-inch armor, with 10-inch at the bases; the turrets for the 6-inch Q.F. guns have 6-inch armor with 3-inch bases, while the hull below the water-line belt is protected for a considerable depth by 4-inch nickel-steel plating. The torpedo armament will consist of one above-water and five submerged tubes. Between the double bottoms there will be 167 water-tight compartments. Krupp supplied the nickel-steel, and a small part of the other armor came from the Carnegie Works, the rest being of home manufacture.

Kamchatka, coaling ship, will have 7,200 tons displacement. Her boilers are six in number, of the Belleville pattern, with a total heating area of 9,388 square feet and grate area of 2,964 square feet, without economizers, and are to develop 2,800 H.P. with 240 pounds pressure of steam.

Kniaz Suvarov.—At the Baltic Shipbuilding Yards the construction of another first-class battleship, to be called the *Knaiz Suvarov*, has been taken in hand.

Novik, improved.—The Schichau Yard at Elbing has just received an order for the building of a new cruiser of an improved *Novik* type. The work is already in hand, and the vessel is to have a speed of 25 knots with engines of 18,000 H.P., and a displacement of some 3,000 tons.

Novik, Cyklov and Sokol.—At the Neva Yard they are proceeding to lay down two new cruisers of the *Novik* type and one at least of the torpedo boats of the *Cyklov* type, of which five are to be laid down when there is room for them. At present there are eight of the *Sokol* type building there, but one will soon be launched.

Yastreb.—This torpedo vessel, built at the Ijora Yard, recently had her steam trials for the official testing of the engines and ascertaining her speed under forced draft. They were held under the superintendence of Rear Admiral Kasherininov

and the experts from the yard, and two runs were first made on the measured mile, giving—first run, speed, 26.67 knots; second, run, 27.01 knots; later the engines were tested by a four-hours' continuous trial at .9 of the full speed with 325 revolutions, after which two further speed runs were made, giving—third run, speed, 26.97 knots; fourth run, 25.47 knots; or a mean speed for the four runs of 26.53 knots, or .03 knot more than the contract. The engines made from 392 to 396 revolutions at a pressure of 190 pounds of working steam in all eight of the boilers. The steam was kept uniformly, and the engines worked quite satisfactorily. The yard will shortly hold trials of the torpedo vessel *Nyrok* and *No. 130*, built on the type of the *Pernov*.

Yenisei.—This torpedo depôt-ship recently carried out her trials under the eye of Rear Admiral Kasherininov, those previously held having been cut short by the twisting of the blades of the port screw. Six diagrams were taken and four trips made over the measured mile, the mean speed being taken at 17.94 knots, the greatest attained being 18.1 knots. The engines worked satisfactorily, developing 4,958 I.H.P., or 258 H.P. over the contract, and no difficulty was experienced in keeping steam, but the expenditure of coal registered was somewhat high, being 4 pounds per I.H.P. The sister ship *Amur* also successfully underwent a second trial under the eyes of the same Admiral as President of the Commission. The mean speed attained in four trips on the measured mile was 17.44 knots: First trip, 17.44 knots; second trip, 17.87 knots; third trip, 16.86 knots; fourth trip, 17.62 knots; average, 17.44 knots. The steam was ample at a pressure of about 250 pounds, and both engines worked quite satisfactorily without heating of the bearings, making on an average 160 revolutions. The expenditure of coal registered was some six tons for all the boilers per hour, or nearly 2.7 pounds per H.P. per hour.

Novik.—Some particulars of the Russian cruiser *Novik*, which has now been handed over to the Russian government by the firm of Schichau, after undergoing her trials, at which she made a speed of 26 knots. The type of vessel required was precisely laid down by the Russian Admiralty, the chief characteristics demanded

being a speed of at least 25 knots, an armament and armor as heavy as possible, combined with a small displacement and thorough sea-going qualities. With regard to the build of the vessel, it was to have a small freeboard and superstructure so as to offer but little target to the enemy's fire, as well as to prevent her being too readily observed. It was evident, therefore, that she was intended to be used for scouting purposes. But this, again, required a large radius of action and good accommodations for the crew. All these various requirements made it difficult for the Russian government to find a firm willing to undertake the work, but finally the plans of Schichau were accepted as satisfactory. The weak part of the design is that it does not permit of the powerful engines, 18,000 horsepower, being entirely below the water line. They cannot, therefore, be covered by the 50-millimeter (nearly 2 inches), armor deck, but protrude above it, where they are protected by an armored dome. The bunker capacity of 900 tons allows of a radius of action at full speed of 900 miles, that distance being travelled in less than 36 hours, or a radius of 5,000 miles at a speed of 14 knots. Her amament consists of six 4.72-inch, twelve 1.85-inch, two 1.45-inch, and one 2.44-inch Baranovski gun, and also five torpedo tubes. The three engines and the twelve water-tube boilers are of the Schichau type. Her trials were made in very rough weather, during which she proved herself thoroughly seaworthy. She has usually been spoken of as a destroyer of torpedo-boat destroyers. Her length is 347 feet 8 inches, beam 40 feet, and draught 16 feet 5 inches.

SWEDEN.

Destroyers.—A new destroyer has been ordered of Yarrow, of the following dimensions: Length, 219.8 feet; beam, 20.5 feet; draught, 7.22 feet; displacement, 320 tons; engines, four cylinders, triple-expansion; boilers, Yarrow water-tube; speed, 31 knots for 3 hours; fuel, coal and oil.

Wasa.—This small coast-guard battleship has been launched. Her principal characteristics are as follows: Length, 287 feet; beam, 49.21 feet; draught, 16.4 feet; displacement, 3,650 tons;

engines, two triple-expansion; I.H.P., 5,500; boilers, Yarrow; speed, 16.5 knots.

TURKEY.

New Cruiser.—The keel of another foreign warship will soon be laid by the William Cramp & Sons Ship and Engine Building Co., and when completed she will fly the crescent of the Ottoman empire.

The new cruiser will have a length of 240 feet on load-water line, with a beam of 42 feet, and with 16 feet draught. This will give her a displacement of 3,250 tons. By the contract she must develop a speed of 22 knots, and this is to be secured by means of twin screws and two triple-expansion engines of 12,000 I.H.P. The steam is to be generated in Niclausse water-tube boilers of the same pattern as those in the Russian ships *Retvizan* and *Variag*.

In armament the vessel will have unusually heavy batteries for a cruiser of her class and size. The main battery consists of two 6-inch quick-fire guns, to be placed one forward and one aft on the middle line of the ship and protected by armored shields; eight 4.7-inch quick-fire guns, arranged in 'midship battery and similarly protected. The secondary battery consists of six 47-millimeter rapid-fire guns and six 1-pounder machine guns, all protected by shields. In addition, there are to be 175 magazine rifles for the crew.

The entire ship will be lighted by electricity, and there will be four search lights, two forward and two aft, located on the superstructure and on the military tops. All of the ammunition hoists are to be operated by electricity, and each by a separate motor. The cruiser is to have two steel masts with military tops, with wooden spars for signaling. In internal fittings the details of construction used in the United States Navy will be closely followed. This applies to ventilation, sanitation, and includes space for quarters for officers and crew. The new cruiser will be fitted as a flagship, and will accommodate 20 officers and 280 men. There is no time clause in the contract, but the vessel is to be turned over to the Ottoman Government complete and ready for use.

MERCHANT STEAMERS.

El Alba.—The new steamship *El Alba* of the Morgan Line has had a successful builders' trial trip. Her engines were turned up to 74 revolutions, and she made an average speed of 16.5 knots.

Kroonland and Finland.—The Willian Cramp & Sons Ship & Engine Building Co. has about completed the main propelling engines to be installed in the new steamships *Kroonland* and *Finland,* building for the International Navigation Co. These vessels are 580 feet between perpendiculars, 70 feet beam, and the loaded draught will be 30 feet. Their registered tonnage will be 12,000. The engines are of vertical, inverted, quadruple-expansion type. Diameters of the cylinders are as follows: High-pressure, 31 inches; first-intermediate, 44 inches; second-intermediate, 62 inches, and low-pressure, 88 inches, with a stroke of 54 inches. The high-pressure and the two intermediate cylinders are fitted with piston valves, and the low-pressure has two treble-ported flat valves. All the valves are worked by a radial valve gear operated by a single eccentric through a quadrant rocking on trunnions. The reversing is obtained by moving the sliding block attached to the valve spindle from one end of this quadrant to the other. The lap and lead are obtained by a separate lever worked from the crosshead of the main engine. This arrangement of the valve motion allows the valves of the engine to be placed at the back, thus bringing the centers of the cylinders much closer together, and, in addition to economizing space in the engine department, adding to the cargo capacity of the ship. The total length of the engines is about 29 feet, which is much less than could be obtained if the ordinary link gear had been used. The reversing gear is controlled by a steam direct-acting engine.

The shafting is of Siemens-Martin steel. The four cranks are each built up separately and are interchangeable. The crank

shaft is 17¼ inches in diameter, the thrust shaft 17¼ inches and the tunnel shaft 16½ inches. The thrust blocks are of the ordinary horseshoe type, of white metal, and there are eight rings. The blades of the propeller are of manganese-bronze, while the boss is of cast steel. The condensers are oblong and support the backs of the cylinders. They are of cast iron and are fitted with brass tubes, the cooling surface being about 7,000 square feet for each condenser. The condensing water to each condenser is circulated by a large centrifugal pump, driven by an independent engine, the connections being made between the two condensers.

The air pumps are driven by a lever working from the cross-head of the second intermediate engine in the usual way. There are also fitted two large evaporators. Two large feed heaters and filtering arrangements are provided. An auxiliary condenser has also been fitted up and when placed on board will have a separate circulating pump so that all the auxiliary machinery in the ship can be worked separately from the propelling engines. There will be an installation of Worthington pumps.

The boilers are single-ended, eight in number, constructed of steel and adapted for a working pressure of 200 pounds per square inch. There are four furnaces to each boiler, or thirty-two in all, these being Brown's suspension type. The boilers are fitted with Serve tubes, 3¼ inches external diameter. The Ellis & Eaves system of induced draft is fitted to the boilers. The boilers are in two compartments, leading into two funnels, which are 98 feet high from the grate level and elliptical in plan, 13 feet 6 inches by 8 feet 6 inches. The fans are eight in number and 7 feet 6 inches in diameter, and are driven direct by Sturtevant engines. These fans, situated directly under the funnels, induce a draft through the furnaces, the air having previously been heated by passing through tubes placed in the way of the waste gases from the furnaces. The inlet of air to the furnaces is through tubes placed in a casing over the boiler, thence down a passage in front of the smoke box at the end of the boilers and into the furnaces. The gases from the furnaces, after passing through the boiler, play around the tubes forming

the air inlet and subsequently pass through the fans into the funnels.—"Marine Review."

New Turbine Steamer.—In consequence of the success of the turbine steamer *King Edward*, another and larger vessel of that type has been ordered. She will have a speed of 21 knots against the *King Edward's* 20½. The Parsons Steam Turbine Co. will supply the engines. The company is also making the machinery for a new turbine destroyer of the same speed as the *Viper*, but designed to consume less coal. The company is also making turbine machinery for three large yachts.—"Marine Review."

Nevadan.—The steamship *Nevadan*, launched by the New York Shipbuilding Company at Camden, N. J., is the first of three vessels which that company are building for the American-Hawaiian Steamship Company. The dimensions are: Length, 371 feet; beam, 46 feet; depth of hold, 34 feet. She will carry about 5,300 tons. The other two ships will be named the *Nebraskan* and *Texan*. A feature of the *Nevadan* is her equipment for burning oil as fuel, if desired. The vessel will run in the service between New York and San Francisco.

Launch of the Shawmut, 11,200 Tons Capacity.—There was launched a few days ago at the works of the Maryland Steel Co., Sparrows Point, Md., the large freight steamer *Shawmut* for the Boston Steamship Co. This is the largest freight steamer up the present time launched in this country, and will only be exceeded in carrying capacity by the 630-foot vessels, now building at New London. The vessel is constructed of steel of the best quality, to the rules of the British Corporation and the American Bureau of Shipping, and is built under the three-deck rule with a continuous shelter deck and bridge for 170 feet amidships on the shelter deck. The vessel has a straight stem and elliptical stern, and is rigged as a two-masted schooner. She has six water-tight bulkheads extending to the upper deck and one water-tight bulkhead extending to the main deck to form a deep tank abaft the machinery space. Of these six bulkheads the forward and after-peak bulkheads extend to the shelter deck. Two partial bulkheads extending to the main deck form a reserve

bunker forward of the boilers and a division bulkhead between the engine and boiler rooms.

The vessel has three complete steel decks and steel bridge deck. The double bottom is built on the cellular system and extends from the fore peak forward to the stern-pipe bulkhead aft. There are nine hatches extending through all the decks, fitted with wooden covers and the necessary strong backs. There will be ten derrick posts which will also be used to ventilate the holds. On the derrick posts there will be twelve booms, 45 feet long; in addition to these there will be four booms on each mast. Twelve steam winches of large capacity will handle the cargo.

Accommodations for the crew are aft between the shelter and upper decks, and in the forecastle forward are fitted staterooms. The officers are accommodated in deck houses around the machinery space, and the captain's saloon and spare rooms are in the deck house forward, with the chart room and pilot house on top. The steering apparatus consists of the Brown Brothers steam tiller in a house aft.

The machinery consists of twin-screw triple-expansion engines, 23½, 39½ and 63 inches in diameter by 45-inch stroke, for 200 pounds pressure. The machinery is designed for 100 revolutions and is of the open-front, inverted, fore-and-aft, triple-expansion type. There will be four single-ended boilers, 15 feet 9 inches in diameter and about 10 feet 6 inches long, designed for 200 pounds working pressure. They are expected to develop 4,500 H.P. with Howden's system of hot draft. There will be the usual complement of pumps. One duplex fire and feed, two Admiralty feed pumps, one Admiralty ballast pump, one duplex salt and fresh water pump, and two simple deck pumps. A feed heater of the Worthington type is to be supplied. Two centrifugal pumps, driven by vertical engines, will supply the water for the condenser. There will also be an electric-lighting plant. This vessel is intended to carry 11,200 tons dead weight cargo and coal on 27 feet 4 inches mean draught, and is expected in point of economy of operation and carrying capacity on said draught to exceed

boats of the same size and type built in Europe.—"Marine Review."

Spokane.—The preliminary runs of this vessel have been made, she having been put over the Navy course at several speeds. Her principal proportions are as follows: Length on load line, 270 feet; beam, 40 feet; draught, 16 feet; engine cylinders, 23½ inches, 40 inches, 66 inches; stroke, 42 inches; steam at boiler, 225; diameter of screw, 12 feet 6 inches; pitch, 16 feet 6 inches; Babcock & Wilcox boilers, 3; heating surface, 7,920 feet; grate surface, 189 feet; two blowers to deliver air into closed ash pan, say ⅜-inch to ½-inch, not to blow out of furnace doors when opened. The smoke pipe, 70 feet, gives .4 draft.

Some little trouble with the ash-pan draft was found at first. The doors were not properly fitted, and the openings in dead-plates had to be closed to get any pressure at all. The engine made, at best, 112 revolutions, throttle wide open, 215 pounds at engine. Speed of ship, 14.66 knots; mean draught, 12 feet 6 inches; I.H.P., 2,575 for the main engine. The boilers did very well; had safety valves blowing, with everything wide open, but difficulty was found in regulating the air pressure. To avoid blowing out furnace doors, therefore, the foreman would shut off the blast entirely before opening the door. Our informant states: "My observation, so far, inclines me to say that you want an air-tight fire room for water-tube boilers. The Scotch marine, with small furnaces, is different; the ash-pit draft can readily be arranged as in the *San Francisco*, but with one large furnace, as on the *Spokane*, the case is entirely different."

BOOK REVIEWS.

MECHANICAL DRAWING, BY F. W. BARTLETT, LIEUTENANT COMMANDER, U. S. N. John Wiley & Sons, New York and London.—In presenting this treatise the author has endeavored to give to the student the methods employed in the Bureau of Steam Engineering, and as this work is principally intended for use at the U. S. Naval Academy, he thought it best also to draw attention to methods practiced by the Bureaus of Ordnance and Construction and Repair. The aim of the writer has been to do away with the practice of copying, and we think this a very praiseworthy move. Instructions are also given in tinting drawings, a practice that is almost entirely given up, but well to be cognizant of. The instructions in the work are remarkably clear and thorough, and should be of great help to those taking up the study of mechanical drawing.

PRACTICAL MARINE ENGINEERING. BY WILLIAM F. DURAND. New York: "Marine Engineering," Incorporated. 706 pages, illustrated. Price $5.00.—The object of Professor Durand in preparing this valuable work was, primarily, to be of assistance to the practical engineer. There is no doubt that he has attained the object aimed at, for the book will not only be of value to men of this class, but also to men of a much higher grade of technical education.

The subjects embraced in the work are the composition, physical properties, and tests of materials of engineering, fuels, boilers, engines and auxiliaries, operation and management of marine machinery, valves and valve gears, steam-engine indicator, special topics and problems relating to the foregoing subjects, propulsion and powering, refrigeration and electricity on board ship. The final section explains the methods of computing elementary problems in arithmetic, geometry, mensuration, physics and me-

chanics, concluding with a list of questions covering the entire subject-matter of the volume.

While all the subjects are treated in the most direct and simple manner, a fair portion of the work being given up to descriptive matter, yet Prof. Durand has spared no pains in endeavoring to make every point covered as plain as possible, and devotes the larger part of the volume to the statement and explanation of the principles governing the operation of marine machinery and of the problems which arise concerning it.

The book, as a whole, is a decided advance upon preceding practical works on the same subject, and is deserving of a place on every engineer's book shelves. It will be of great advantage to machinists in both the Navy and Merchant Marine in aiding them in preparing for examinations for higher grades.

In reading through this work we were surprised that such thorough, practical knowledge as is shown in its preparation should be possessed by an author who for years has been identified more particularly with engineering in its higher branches, such a combination of theory and practice in one person being seldom found.

ASSOCIATION NOTES.

At a meeting of the Council of the Society held on January 18th, the question of the illegal form of the votes which had been received for the annual election of officers and the awarding of the prize for the best original article presented during the year, was considered.

Under the by-laws of the Society these votes were required to be signed and then forwarded in a sealed envelope to the Secretary-Treasurer of the Society. These envelopes were then to be opened and the votes counted at the regular annual meeting of the Society.

None of the envelopes received which contained votes were marked in such a way as to identify them as containing votes. This omission necessitated that they should be opened. Upon opening them, fully 90 per cent. of the votes were found to be unsigned.

After duly considering the question, it was decided so throw out all votes which had been received or which would be received as a result of the first call, and to issue new voting slips with a marked envelope for their enclosure, and the Secretary-Treasurer was so instructed.

The Secretary-Treasurer then presented his annual statement of the condition of the Society, which, after being audited by the other members of the Council, was approved. The statement as to finances and membership of the Society is hereto appended.

STATEMENT.

Balance on hand January 7, 1901		$4,969.43
RECEIPTS.		
Received from dues of members and associates	$2,241.25	
advertisements	1,709.98	
sale of JOURNAL and subscriptions	740.25	
Interest on deposits	93.61	
		4,785.09
Total on hand and received		$9,754.52

EXPENDITURES.

Printing and engraving	$3,562.82	
Salary of Secretary-Treasurer to December 15	862.50	
Postage, miscellaneous expenses, etc.	322.14	
		4,747.46
Balance on hand and on deposit January 1, 1902		$5,007.06

MEMBERSHIP, ETC.

Number of honorary members	12
members	257
associates	250
subscribers	90
advertisers	68
exchanges	50

Respectfully submitted.

C. W. DYSON,
Lieutenant, U. S. Navy.

Examined and approved.

(Signed) C. W. RAE, *Commander, U. S. N.*
F. H. BAILEY, *Lieutenant Commander, U. S. N.*
C. E. ROMMEL, *Lieutenant, U. S. N.*

The Council then adjourned.

(Signed) C. W. RAE, *Commander, U. S. N.,*
President.

CHARLES W. DYSON, *U. S. N.,*
Secretary-Treasurer.

The attention of members and associates is called to the following notice which is issued by direction of the Council:

The annual meeting of the Society for the election of officers for the current year and the award of the prize to the best original article of the past year, will be held at the Navy Department, at 8 p. m., on the evening of the last Friday in April.

(Signed) C. W. DYSON,
Lieutenant, U. S. N., Secretary-Treasurer.